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SURGICAL TREATMENT

A Practical Treatise
on the Therapy of Surgical Diseases for the Use of
Practitioners and Students of Surgery

BY

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IN THREE VOLUMES
WITH 2400 ILLUSTRATIONS

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"The most important part
of my business is to know
what ought to be done."

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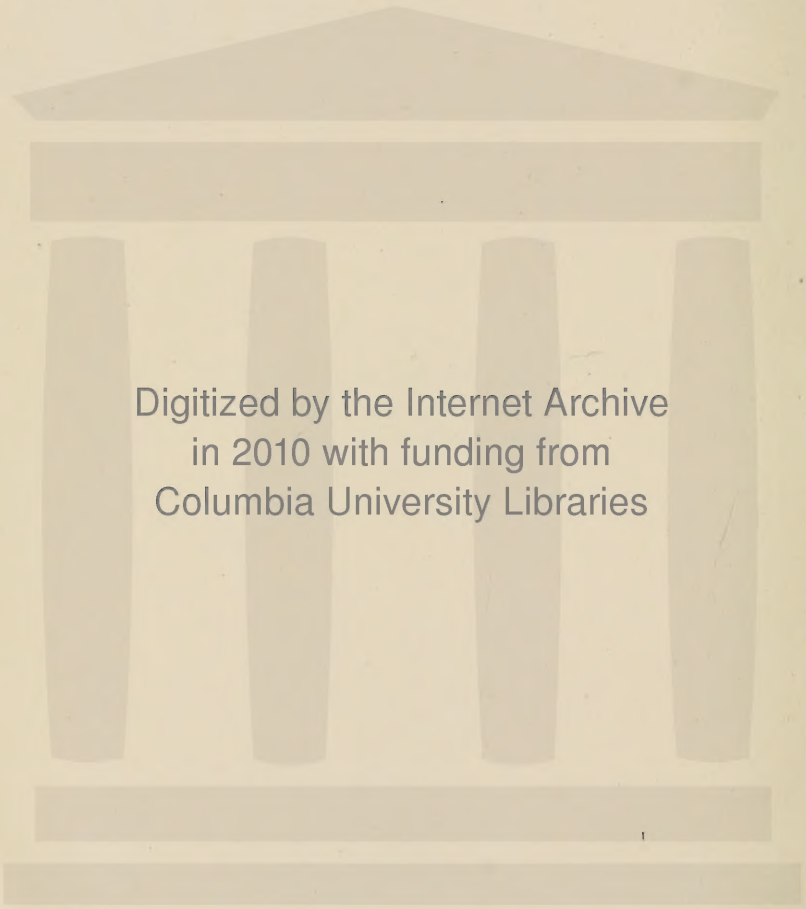
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DEDICATED
TO THOSE WHO SUFFER FROM
SURGICAL DISEASES AND INJURIES;
WITH THE HOPE THAT
SCIENCE, SKILL, AND KINDNESS
MAY BE BROUGHT TO THEIR AID,
TO THE END THAT THEY SHALL BE
HEALED

PREFACE

This work has been written in the interest of the surgical patient. The object has been to place in the hands of the surgeon the means for rendering help in every surgical condition under all circumstances. The aim has been to make this information easily accessible, and its application practical.

In most surgical diseases there is an ideal course of treatment which may be pursued and which represents the highest possibility of surgery. The author has endeavored to present this maximum of treatment. Every consideration has been given to direct the surgeon toward the ideal of perfection. In many instances its application requires especial skill and knowledge. The author is aware that circumstances may surround both the patient and the surgeon which make impossible the applying of the ideal measures, or render such attempts inexpedient. As an admission of these circumstances this work presents alternatives of treatment which may be employed if the best thing possible cannot be done.

The fact that the author has had constantly in mind the interest of the patient, as the object of supreme consideration, has comipelled the concession that there are differences in surgical ability in the applcation of treatment. As the purpose of this work is not to glorify surgery, but to cure surgical patients, this fact is frankly faced. In surgical diseases the mortality varies with the skill of the surgeon. The author has attempted to adapt to this fact the therapeutic advice which he gives. Thus, in many conditions, both operative and nonoperative treatments are described; and in some diseases operative procedures are given which should be carried out by the experienced surgeon only, and methods are described which are adapted to the less experienced surgeon but to which the experienced operator need not resort. All this is made necessary by the fact that in the treatment of surgical conditions there is not only a pathological hazard which is capable of modifying the outcome of the disease, but a surgical hazard as well. As the pathology of surgical diseases is a variable factor in every case, so also is the surgical treatment which the patient may command a variable factor.

These are not altogether unhappy circumstances. The average surgeon is capable of most efficient administration of the principles of treatment; and above and beyond the average surgeon is a great class of experts whose capabilities, in relieving suffering, prolonging life, and restoring to efficiency the damaged and diseased, are the marvel of this age, and represent the most beneficent expression of human handicraft.

The author hopes for the day when all surgeons who are entrusted with the lives of human beings shall be so equipped that they can apply the ideal treatment in all cases which come to their hands, and when all patients with surgical diseases can command access to the environment which shall provide them the surest guarantee of recovery.

Surgery is an art based upon a complex of sciences. It is always in a developmental stage. Accordingly the author has endeavored to inspire the reader with the spirit of originality, to teach him not only how to do, but to suggest to him new lines of action, to set him thinking on the problem of treatment from his own standpoint. The hope of surgery, like all learning,

lies in emancipation from the thraldom of authority. In this work many expedients will be found to be briefly mentioned for the purpose of suggestion, in order that the reader may be impelled to originality. For this reason much of the normal anatomy of the parts is given, and anatomical illustrations are freely employed.

It is assumed that the surgeon who turns to these pages for help is familiar with the fundamentals of surgical pathology and diagnosis.

Prophylaxis is regarded as a part of pretreatment, and prognosis is so intimately associated with the results of treatment, that each is accorded as much attention as possible.

While large consideration has been given to new methods, nothing has been introduced for the sake of novelty. In the presence of the newer modes of treatment, the fact has not been lost sight of, that there are old methods and old agents of surgical therapy which have survived the trials of time and which are destined to outlive the newer things which are now vaunted in their places.

In a work such as this, written wholly by a single individual, the literature of the special departments of surgery must needs have been freely consulted. Duplication and overlapping of subjects has been avoided by individual authorship. By the use of cross-references much space has been saved, and, it is hoped, the working value of the publication increased.

The author has seen fit to make certain variations from the current classifications. Among these it will be noted that the treatment of infected wounds is discussed under inflammations.

It will be observed that there are comparatively few references to the discoverers of methods and of instruments. This is because the more the author has searched the literature the more he has been struck by the fallacy of our proper-name nomenclature in surgery. Most instruments and procedures, bearing proper names, were used before the time of the individual whose name they bear. All of them are the product of a long series of antecedent workers. No surgeon is isolated. Surgery is harmonized by the spirit of mutual aid. Each surgeon's work is composite. The operation he is performing, however original it may seem, is but a small part his own.

The author has endeavored to give credit to surgeons and to literary references wherever it has seemed called for. He desires that in quoting from this work others shall not attribute originality to apparently new methods which are not connected with some surgeon's name. Although many operations and methods of treatment, so far as is known to the author, are here described for the first time, they are all based upon well-known surgical principles, common to all surgeons. The author has avoided, so far as possible, attributing to others originality which cannot be confirmed, and desires that the same consideration shall be shown to him.

That this work may prove a practical source of strength to the surgeon in his encounters with disease, and that it may contribute to the promotion of the highest ideals of surgery, is the purpose which has prompted its creation.

JAMES PETER WARBASSE.

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BROOKLYN, NEW YORK.

CONTENTS

	Page
General Principles of Surgical Treatment	17
Ancestral and Personal Peculiarities	18
Nourishment	19
Fresh Air	21
Nursing	22
Asepsis and Antisepsis	27
Infection	27
Sterilization	28
Surgical Materials, Their Preparation and Sterilization	33
Ligatures and Sutures	33
Dressing Materials	39
Sponges and Pads	42
Drainage Materials	45
Surgical Accessories	48
Bandages	55
Solutions, Applications, and Antiseptics	57
Caustics	73
Surgical Instruments	75
Operating Tables	85
Emergency Instruments and Surgical Expedients	87
Care and Sterilization of Instruments	89
Anesthesia and Anesthetics	92
General Anesthesia	92
Rectal Anesthesia	110
Intravenous Anesthesia	114
Hypodermic Anesthesia	123
Pharyngeal Anesthesia	124
Laryngeal Anesthesia	125
Intratracheal Anesthesia	125
Hypnotic Anesthesia	126
Local Anesthesia	127
Spinal Anesthesia	155
Epidural Sacral Anesthesia	162
Parasacral Anesthesia	162
Intravenous General Anesthesia	164
Wounds and Operations	166
The Operating Room	166
Operating Personnel	169
Preparation for Operation	172
General Preparation of Patient	176
Local Preparation of Patient	177
Special Preparation of Patient	180
The Making of Surgical Wounds	184
Accidental Wounds	186
Closure of Wounds	187
Drainage of Wounds	204
Dressings	205
Complications of Wounds	211
Shock	213
Special Wounds	218
Postoperative Treatment	225
Inflammations	228
Acute Inflammations	228
Artificial Hyperemia	229
Infected Wounds	237
Physiologic Treatment	239

PAGE
Antiseptic Treatment . . . 242
Chronic Inflammations . . . 243
SURGICAL FEVERS AND INFECTIONS . . . 255
Vaccines, Serums and Antitoxins . . . 255
Septicemia . . . 259
Pyemia . . . 260
Erysipelas . . . 262
Tetanus . . . 264
Gas Bacillus Infection . . . 270
Anthrax . . . 271
Actinomycosis . . . 272
Glanders . . . 273
Hydrophobia . . . 273
Snake Bite . . . 274
Bites and Stings of Insects . . . 275
Tuberculosis . . . 276
Syphilis . . . 283
FISTULAS AND SINUSES, ULCERATION AND GANGRENE . . . 304
Fistulas . . . 304
Sinuses . . . 305
Ulcers . . . 308
Gangrene . . . 315
NUTRITIVE DISTURBANCES . . . 321
Scurvy, Rickets, Acromegaly . . . 321
Giantism, Dwarfism, Cretinism . . . 322
TUMORS . . . 323
BLOOD AND BLOOD-VESSELS . . . 334
Hemorrhage . . . 334
Proctoclysis . . . 344
Hypodermoclysis . . . 344
Infusions . . . 346
Transfusion . . . 348
Special Arteries . . . 360
Arteries . . . 371
Aneurism . . . 380
Occlusion and Ligation of Arteries . . . 401
Veins . . . 446
Wounds of Veins . . . 446
Phlebitis . . . 447
Varicose Veins . . . 448
Thrombosis and Embolism . . . 454
Coagulability of Blood . . . 458
LYMPHATIC SYSTEM . . . 460
Wounds . . . 460
Inflammations . . . 461
Lymphedema . . . 462
Lymphoma . . . 464
Leukemia . . . 466
DISEASES OF BONES . . . 467
Inflammations . . . 467
Caries and Necrosis . . . 468
Osteomyelitis . . . 469
Tuberculosis of Bone . . . 469
Tumors . . . 470
Deforming Diseases . . . 471
FRACTURES . . . 472
General Considerations . . . 472
Immediate Treatment . . . 472
Reduction . . . 474
Immobilization . . . 476
Splints . . . 477
Plaster-of-Paris . . . 477
Traction and Extension . . . 485
Massage . . . 500
Operative Treatment . . . 502
Bone Grafting . . . 509

PAGE
Joint Fractures . . . 518
Compound Fractures . . . 518
Fracture Dislocations . . . 521
Ambulant Treatment . . . 522
Treatment of Complications . . . 524
Fractures in the Newborn . . . 529
Special Fractures . . . 532
DISLOCATIONS . . . 610
General Considerations . . . 610
Complications . . . 611
Compound Dislocations . . . 612
Old Unreduced Dislocations . . . 612
Habitual and Recurrent Dislocations . . . 612
Congenital Dislocations . . . 613
Special Dislocations . . . 618
DISEASES OF JOINTS . . . 650
Sprains . . . 650
Dislocation of Cartilages . . . 652
Internal Derangements . . . 653
Wounds of Joints . . . 654
Synovitis and Arthritis . . . 657
Tuberculosis of Joints . . . 663
Tuberculosis of Special Joints . . . 665
Syphilis of Joints . . . 680
Neuroses of Joints . . . 681
Malpositions due to Contractures . . . 682
Ankylosis . . . 686
OPERATIONS ON BONES AND JOINTS . . . 688
Operations for Inflammations of Bone . . . 692
Bone-cavity Filling . . . 701
Resection of Bone for Tumors . . . 706
Arthrectomy . . . 710
Osteoplastic Operations . . . 710
Osteotomy of Long Bones . . . 711
Excisions and Resections of Bones . . . 717
Operations on Joints . . . 737
Arthrodesis . . . 738
Excisions of Joints . . . 741
Arthrotomy . . . 755
Prevention of Ankylosis . . . 756
Operations for Ankylosis . . . 757
Transplantation of Joints . . . 767
Osteoplastic Joint Operations . . . 768
Operations to Lengthen Bones . . . 770
Technic of Bone Grafting . . . 772
MUSCLES, TENDONS, FASCIÆ AND BURSÆ . . . 788
Muscles . . . 788
Tendons . . . 796
Repair of Tendons . . . 796
Lengthening of Tendons . . . 799
Reconstruction of Tendons . . . 803
Shortening of Tendons . . . 804
Tendon Grafting . . . 805
Tenotomy . . . 813
Prevention of Adhesions . . . 816
Tenosynovitis . . . 817
Ganglion . . . 818
Fascia . . . 818
Bursæ . . . 819
SKIN AND ITS APPENDAGES . . . 820
Traumatisms . . . 820
Burns . . . 821
Infections . . . 825
Hypertrophic Diseases . . . 840
Atrophic Diseases . . . 843
Neuroses . . . 843

PAGE
Glandular Diseases 844
Hair and Nails 846
Animal Parasites 848
Cosmetics 849
NERVES 850
Contusions 851
Compression 851
Operations on Nerves 852
Suturing 853
Bridging 855
Transplantation 856
Implantation 857
Stretching 860
Neurectomy 861
Neurotomy 861
Neuritis 861
Neuralgia 862
Neuralgia of Special Nerves 865
Tumors of Nerves 880
Diseases of Special Nerves 881

INDEX OF NAMES 901
INDEX OF SUBJECTS 905

SURGICAL TREATMENT

GENERAL PRINCIPLES OF SURGICAL TREATMENT

Surgical treatment is the oldest branch of surgery. It was developed empirically into an art long before there was understanding of pathology and diagnosis. At the present time it no longer stands alone; its perfection now rests upon basic knowledge. The most important prerequisite for successful treatment is an understanding of the normal and pathological anatomy and the nature of disease. The surgeon who would equip himself best to treat surgical disorders must first understand their causes, pathology, and manifestations.

Surgical diseases are those which involve the external parts of the body and those which are amenable to manual treatment. The aid of the natural forces of repair is invoked in all diseases, but surgical diseases are those in the treatment of which the aid of manual art is required. The province of the surgeon is a large one, touching and overlapping all of the other departments of medicine. The peculiarity of surgery is that the surgeon himself is a part of the treatment.

Surgical diseases are not made up so largely from the self-limiting class as are medical diseases. The natural tendency of most of the medical, or so-called internal diseases is toward spontaneous recovery. Diseases which have not this tendency, but for which something mechanical can be done, are placed in the surgical class. The domain of surgery is constantly enlarged by the addition of diseases which are found to be not amenable to medical treatment. Abscess of the lung, the neuralgias, blood disorders, and many of the abdominal diseases are examples. On the other hand there are, perhaps, no diseases which have passed from the distinctly surgical to the medical category.

We should not make the mistake to draw too positively a line of division between these two classes of disorders. The same principles of constitutional treatment and general care of the patient apply in surgical as in medical diseases; and the same factors influencing the course of disease are to be considered. In order to secure the best results in surgical treatment, the surgeon must not only apply himself to the specific ailment of the patient, but he must give the individual as a whole his best consideration.

When a person suffering with a surgical malady comes under the care of a surgeon, the one guiding principle which the surgeon should have always before him is to do what is best for the patient, to the end that he may be cured most quickly and completely. In doing this, the surgeon has a right to abstain from impairment of his own ability to perform the same service for others. The surgeon should treat one patient at a time, and give his best concentrated effort to that patient, irrespective of the prospects of pay or appreciation. By so doing he may expect to secure the most substantial rewards.

Race.—In the treatment of surgical diseases there are certain conditions which influence the course of disease, and with which the surgeon should be

familiar. Among these are *racial differences*. In the temperate climates the negro is particularly susceptible to tuberculosis, and fistula in ano; and carcinoma of the breast and uterus develop more commonly than in Arian women. On the other hand appendicitis, piles, intestinal infections, gall-bladder infections, and enlarged prostate are less prone to occur in the negro. The negro as seen in temperate climates is less resistant to disease and injury than are the whites, and the death-rate is higher at all ages.

In the surgery of the head it should be borne in mind that the skull of the African negro is much thicker than that of the white. Mulattoes or mixed breeds present the weaknesses of both races and more deficient resistance than either. Carcinoma is less apt to occur among Indians, and still less apt to develop among the Chinese. Among the American Indians and Mexicans most all carcinomata occur in the breast or womb.

The Jewish people present extraordinary resistance to bad hygiene; they bear surgical operations well; those living under the stress of city life are prone to the development of piles and other rectal affections and to infections through the portal system, probably entering through anal fissures and abrasions. Injuries and operations are borne particularly well by the peoples which live exclusively, or nearly so, on a vegetable diet—the Chinese, Japanese, Indians, Mohammedans, and the peasantry of Europe.

Ancestral and Family Peculiarities.—These are transmitted and often have an important bearing upon the resistance of the individual in recovering from disease. Hemophilia is one of these conditions, and its history should be inquired for. There are certain diatheses which are peculiar to families and which, cropping out during the treatment of surgical diseases, should be recognized and account taken of them. Diabetes, gout, certain nervous diseases, palsies, degenerative changes in the nervous system, insanity and epilepsy belong to this class.

Sex.—The peculiarities of sex are also to be considered. Among the young these differences are slight, but among adults it is noteworthy that women bear pain better than men; they also suffer less from confinement in bed; their physical resistance on the whole is less than that of men; they are more susceptible to nervous disturbances arising as sequelæ to operations and injuries. Dementia following traumatism is probably more common in women. Good cosmetic results are more important to women than to men.

Occupation.—The occupation of the patient has a bearing on surgical treatment. The strength and suppleness of the laborer's or mechanic's hands and limbs are most important to him; whereas, often with the business man, the item of time required for a cure is a more important factor. The occupation of the patient must often determine whether time shall be saved or whether the best possible surgical result shall be secured. Questions of this nature come up in the treatment of destructive injuries of the extremities and in extremely chronic diseases. The loss of a member is sometimes of less importance to the patient than the loss of the time which would be necessary to effect a cure.

Habits.—The previous habits or diseases of the individual often have an influence upon the treatment of surgical cases. Wounds heal more slowly in the syphilitic, and in such patients the surgeon owes it to himself and his assistants to take care lest they become infected. Patients who have habitually taken much *alcohol* present many peculiarities. They take general anesthetics with greater difficulty and danger; they must be guarded more carefully against congestion and acute failure of the internal eliminating organs; they suffer most from the dangers of deficient nourishment after operation or injury; they are prone to develop delirium tremens; and their general

resistance in every respect is lower than that of non-alcoholic individuals. This is not only true of the confirmed drunkard who shows plainly the outward signs of alcoholic degeneration, but also of the more moderate drinker who apparently is healthy and who first shows the damaging effects of alcohol after some injury or surgical disease.

Resistance.—The natural physical resistance of individuals to surgical disease is very variable. Some individuals possess great physical resisting power while others seem to have but meager vitality. Traumatism and disease generally are resisted better by persons of healthy ancestry, by those who have lived hygienically, and by the more primitive or simple people who have not yet come under the influences of so-called civilization. The more highly cultivated types are depressed more by the shock of injury and operation, and they are more susceptible to the damaging effects of infections, with the exception of those infections to which ancestral habituation has rendered them immune. The more closely to the soil races have lived, the greater is their resistance to disease and injury when compared with those who have lived in the environment and occupations peculiar to towns and cities. A preëxisting defect in a single organ often becomes a matter of serious concern in the presence of surgical disease; and thus the surgeon may be called upon to pay especial attention to the heart, or the kidneys, or the lungs when the other parts of the body are functionating well. The obese are notoriously deficient in vital resistance.

Age.—The age of the patient is also a matter for consideration. Children are particularly susceptible to shock. They have, however, greater recuperative elasticity. While more easily depressed, they seem to recover from more profound states of depression than adults.

The tissues of children are more tractile than those of adults, and deformities which in adults require cutting can often be cured by being fixed in an over-corrected position.

Light chloroform or ether anesthesia is best for children. Morphin, cocain, and spinal anesthesia are objectionable.

Old age presents the peculiarity of specific weaknesses of special organs, particularly the circulatory system. The psychic element in the treatment of the aged is most important. Their prejudices, habits, and whims should not be antagonized. During sickness is a dangerous time to attempt the inauguration of reforms in old people. During illness their previous habits, so long as not positively prejudicial to health, should be continued.

Immediate Conditions.—Besides the above remote conditions, there are ertain immediate conditions which influence the treatment and course of urgical diseases.

Nourishment.—Special nourishment is required in certain diseases, but in all surgical cases the patient's nourishment should be regarded as a part of the treatment. In general, the nourishment should be simple and adequate. The two extremes should be avoided. The patient should not be put upon a starvation diet, as was once the custom, nor should he be "fed up" to the degree of overfilling his intestine. Of the two evils the latter is, perhaps, the greater. His nourishment should be kept up to the highest standard compatible with the absence of harmful excess, for the reason that in infective diseases salutary leukocytosis depends upon good nourishment, and in the reparative processes healthy tissue-building requires nourishing food. In order to secure the best general results the food should combine the necessary proportions of proteid, hydrocarbon, mineral salts, and water, to which may be added vegetable acids as the taste of the individual may require. Vitamins and the chlorophyl of fresh vegetables are also essential for the best

nourishment. The simplest forms in which these foods may be found are the best. Eggs, milk, dry bread, butter, simple vegetables and a little meat are the most desirable foods. Butter-milk, and the juices of the orange, lemon or grape are valuable addenda. Food should be thoroughly masticated, and fluids should not be taken cold with meals. If these rules are followed and no solid boluses are swallowed, but mastication is carried to the degree that the food is chewed until it disappears in solution in the saliva, several things will be observed: the time required to eat a given amount of food will be much increased; the amount of food required will be much diminished; digestion and assimilation will be more normal; there will be less intestinal gas; the bowels will act more regularly; and there will be a better general feeling of well-being. For these reasons patients should have teeth adequate for mastication; that means at least two molar teeth in each jaw on each side.

There is much talk of sick-room dainties. Better results will be secured by attention to the above simple hygienic principles than by coaxing patients without appetite to take insignificant amounts of fancy foods against their wills. There is usually some better measure than coaxing a patient to eat who has no appetite.

The surgical sick are particularly prone to develop the disturbances incident to the accumulation of fermenting food in the intestine. Constipation; tympanites; general toxemia, as manifested by headache, neuralgias and "rheumatism," are their common disturbances. These are to be avoided by a modicum of simple, well-masticated food. This is particularly important for the obese, whose nutritive unbalance has loaded them with an excess of hydrocarbon, and who should be required to supply from their own tissues the important food for the nourishment of their leukocytes. A person lying in bed requires surprisingly little food; and one of the harms done to surgical patients both in private and in hospital treatment is in overfeeding.

Clinical studies have shown that the number and vitality of the leukocytes, which a patient is able to produce, depend upon the general nourishment and vitality of the individual, and that the one food which is most capable of favorably influencing leukocytosis is animal fat. That means cream, butter, or the fat of meat. Inasmuch as the question of infection plays so important a part in all inflammatory diseases and in wounds, both accidental and operative, and inasmuch as the overcoming of infection is largely a matter of leukocytosis and antibodies, the importance of maintaining surgical patients in as high a state of vital resistance as possible and of favoring their leukocyte-producing power is imperative. The surgeon succeeds best in treatment who takes the most advantage of the patient's own natural powers as an aid to his recovery.

Besides food taken by the mouth, nourishment may be injected in a predigested condition into the bowel by way of the rectum (see Nutrient Enemata, Vol. II).

The use of *nutrient intravenous and subcutaneous injections* may be resorted to in certain cases. *Grape sugar* may be given intravenously in 5 to 10 per cent. solutions, or even in concentrated solutions, as high as 30 per cent. For subcutaneous injections a 5 per cent. solution is used. As much as 1000 c.c. of the weaker solutions may be given in the course of twenty-four hours. This gives important carbohydrate nourishment which is immediately available for metabolism. It is especially valuable as a post-operative measure. In diseases associated with vomiting and lack of nourishment, and especially in conditions complicated by loss of bodily fluids, it is particularly useful. Glucose may be given dissolved with salt or alone in water. It should be filtered and sterilized.

As an emergency treatment in severe infections and intoxications, and weak heart action, in which the gravity of the condition is manifested by diminished excretion of urine, a 30 per cent. solution of glucose may be used with advantage. About 250 c.c. or 300 c.c. may be injected slowly into a vein. An hour may be given to injecting this amount, or it may be given in divided doses. The injection may be repeated as often as seems necessary. Such concentrated solution seems to do no harm to the blood. Some temporary glycosuria appears if the amount is large. It increases the strength of the muscles, abstracts fluid from the tissues and adds it to the blood, raises the blood-pressure, increases the excretion of urine, and supplies immediate nourishment. This removes toxins. It may also be used to remove accumulated anesthetics after operation. It is especially valuable in cases with kidney derangement in which the use of salt is contraindicated.

Glucose may be obtained in emergency from raisins. The raisins should be crushed and have boiling water poured over them. The grape sugar dissolves out and provides a valuable nourishment.

The use of *subcutaneous injections of proteid material* is possible. The yolk of fresh eggs may be employed. To the yolk of one egg should be added 5 Gm. of 1 per cent. iodized glycerin and 5 Gm. of physiologic salt solution. This mixture is injected into the subcutaneous connective tissue of the buttocks. The material is rapidly absorbed, and serves as nourishment and stimulant to phagocytosis. In cases in which it is further necessary to supply fluids to the body, normal saline injections may be added. These injections may be used as often as indicated. The subcutaneous injection of proteid substances is not to be recommended as a routine because of the dangers of anaphylaxis and local infection.

Fresh Air.—Surgical treatment can not be discussed adequately without an allusion to the value of *fresh air*. This is the one branch of treatment in which modern therapy fails. By fresh air is meant air in mass motion, having the range of humidity-temperature ratio which characterizes the average outdoor air. Indoor air can be freshened artificially but it is a difficult process, and much better results are secured by taking the patient out into the outdoor air, or bringing itdirectly and in motion to him.

There is much theoretical appreciation of the virtue of fresh air, but all too little advantage is taken of its curative help. Architects ostensibly take it in account in the construction of hospitals, but after all we find the patients lying in stagnant air, often in wards pregnant with odors which harken back to the epoch of the pest house. Patients still grow "hospitalized," which often is another word for "deprived of the blessing of fresh air." The pallor of the faces in the hospital ward is not always the result of the patient's disease: it too often is the result of denying him the cheapest and most abundant commodity in nature.

One of the greatest aids in the treatment of the sick is fresh air. By this is not meant the niggardly doling out of air through cracks, crevices, and long and tortuous air ducts; but an abundance of fresh air, secured by taking the patient out into it, or admitted through widely opened windows, or through commodious and direct ventilators, such as are but rarely installed. A healthy man requires fresh air for the most effective work, and when he becomes sick his best interests demand it even more than when he is well; but unhappily when sick he is apt to be given less, as though smothering him in his own excretions were actual care. The last few years have witnessed the abolition of the "low diet" for the patient struggling with an infection. He is now fortified with something better than beef-tea. It is earnestly to be hoped that the therapy of the near future will see as much consideration shown to the red blood-cells as is now shown to the white.

All surgical patients, whether suffering with wounds, injuries, infections, or convalescent from operations, will do better in the presence of an abundance of fresh air. So far in surgery this is practically applied only to tuberculosis; but the surgeon who wishes to be in the lead of scientific thought and practice must know that it is in no wise a treatment of value peculiar to tuberculosis alone, and he will give every patient the advantages of fresh air in abundance.

Environment plays an important rôle in surgical treatment. The dangers of physical damage to patients with fresh wounds, becoming contaminated by virulent infective cases such as erysipelas, is now a matter of the past. Such foci of infection are now isolated from other patients by the practical application of the principles of aseptic surgery which eliminates the danger of the transmission of infection. But the psychology of environment is especially worthy of consideration. The issue between life and death may be decided by the mental effect of the patient's surroundings. This, of

FIG. 1.—BED.
Tubular iron frame, woven wire steel springs, hair mattress and sheet.

course, is most important in the cases of persons of nervous sensitiveness, patients about to undergo operation, and those suffering with grave disorders. In all cases the best ends will be served by surrounding patients with conditions which make for brightness, optimism and confidence. It is important that what transpires in their presence shall not have a depressing effect. They should be spared witnessing suffering or suggestions of death.

We owe it to the sick, whose lives depend upon our administrations, to give them the best we have to offer, and at least not to add further depressants to their disease. The sick-room or ward should be bright, clean and cheering, not only as to its walls and floors but also as to its personnel. In the well-regulated hospital this condition is ideal: there is prompt attention to the essentials, unnecessary noises are absent, the bed clothing is clean and simple, uniformity prevails, here and there a touch of the esthetic relieves the tedium of plainness, and orderliness is everywhere observed.

Nursing.—Good nursing is now recognized as an essential feature in surgical treatment. A nurse can supplement the surgeon in the most important

elements of care of the patient. She has three chief functions: the carrying out of the details of treatment, running through the day and night, which the surgeon prescribes; the observation of the patient's condition, watching for changes, making clinical tests, and reporting when necessary upon new developments in the course of the disease; and finally the recording, for purposes of history and clinical study, of treatments and the conditions of the patient. To these she should add the general spirit of helpfulness, and inspire the patient with hope and confidence by her own willingness and efficiency.

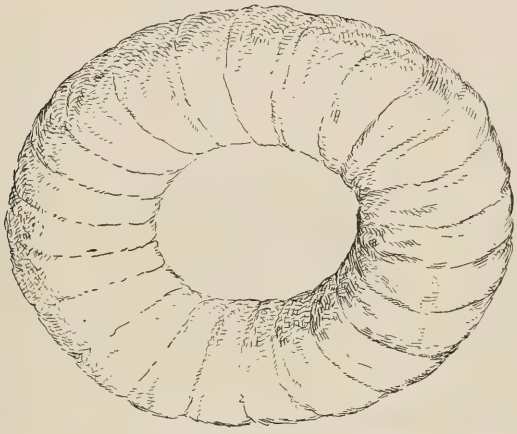


FIG. 2.—RING USED IN PREVENTION AND TREATMENT OF BED SORES.

So important are the nurse and good nursing, as adjuncts to surgical treatment, that it may properly be said that the high position to which modern surgery has attained would have been impossible without them.

The bed upon which the surgical patient lies should be high and narrow so as to make all parts of the patient easily accessible (Fig. 1). The mattress should be firm, preferably of hair, and have spread over it a rubber sheet. The bed sheets should be smooth and clean, and the covering for warmth should be as simple as possible. Unwashable quilts are objectionable. The head

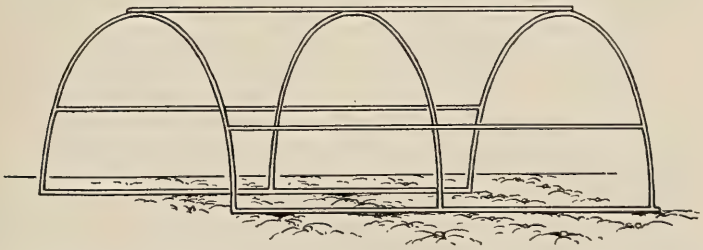


FIG. 3 —BED CRADLE TO KEEP THE WEIGHT OF BED CLOTHING FROM THE LEG OR BODY. Made of heavy wire.

of the bed should be toward the light for the protection of the patient's eyes. The best beds are provided with means for elevating the upper end in order to secure an elevation of the trunk or shoulders into a semi-recumbent or sitting position. There are also to be had wheels which may be attached to the four corners of the bed to permit its easy moving without disturbing the patient. Air cushions and rings (Fig. 2) or rubber cushions filled with warm water are employed to protect tender parts from the bed or to prevent bed

sores in feeble patients. For keeping the weight of the bed clothes from the parts a *bed cradle* (Fig. 3) is useful. Such a cradle may be extemporized from a box or from barrel hoops (Fig. 4).

In order to permit the patient to move himself a crane is swung over the bed with a strap and handle hanging within reach, or some other device by which the patient may raise and move himself. The skin of the patient

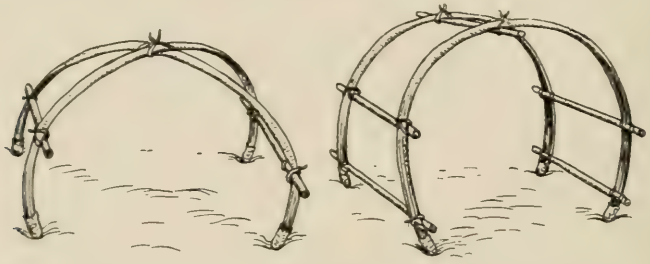


FIG. 4.—BED CRADLES EXTEMPORIZED FROM BARREL HOOPS.

should be kept healthy by a daily bath, and bony prominences upon which there is pressure should be rubbed with alcohol and kept dusted with zinc oxide. The skin should always be dry. Wet sheets should be removed at once. The bed-pan and urinal are indispensible for receiving the discharges from the bowel and bladder. For patients who can not be lifted onto the bed-pan a bed-frame with a covering of canvas, having a hole under the pelvis, is kept beneath the patient. This frame may be lifted up and the vessel for receiving the discharges slid under. The wedge-shaped *bed-pan* (Fig. 5) now in use makes this bed-frame rarely necessary. The douch pan (Fig. 6) is also used to receive the discharges of urine and feces.

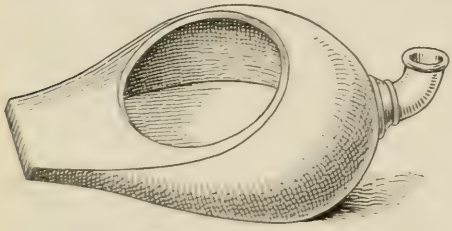


FIG. 5.—BED-PAN.

In order to elevate the foot of the bed to cause the blood to gravitate to the head in cases of syncope, or to elevate the head of the bed to cause the contents of the abdomen to gravitate toward the pelvis, chairs may be placed under the end to be elevated, or the special bed-lift may be used (Fig. 7).

Mental State of Patient.—An element in surgical treatment, which was formerly much ignored but the importance of which is now becoming more and more appreciated, is the *mental state* of the patient. That the mind exercises a potent influence over the functions of the vital organs is well recognized, and the surgeon who disregards this neglects to call to his aid a most useful therapeutic principle. Constantly the surgeon has under his care patients whose lives hang in the balance. Often after operation, it is not a matter of infection, or nourishment, or destructive disease of a vital organ, but a general functional failure of the eliminative organs or of the internal secretions; and the slightest turn for the better means recovery and for the worse means death. Often the surgeon

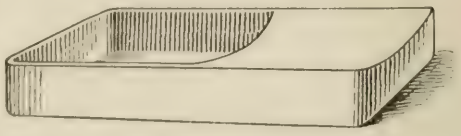


FIG. 6.—DOUCHE-PAN.

stands helpless before these cases. Stimulants were his resort until their uselessness and danger were determined. He then turned to the eliminative organs and to the vascular systems, cleansed the primæ viæ, filled the vessels with fluids and washed out the excretory glands.

These latter measures have undoubtedly been of service, but still, without recognizable serious organic disease, patients sink and die. These are commonly those in whom there is a high degree of nervous sensitiveness. Here disaster might have been averted by the surgeon who inspires confidence, whose manner is one of hopefulness, who suggests recovery, and who compels an air of optimism in assistants and nurses. The surgeon can do still more than this; besides the passive air of hopefulness, an actual aggressive application of these principles may be employed as a deliberately planned therapeutic measure. That does not mean necessarily that the surgeon himself shall give his time to mental treatment, but it does mean that he is responsible

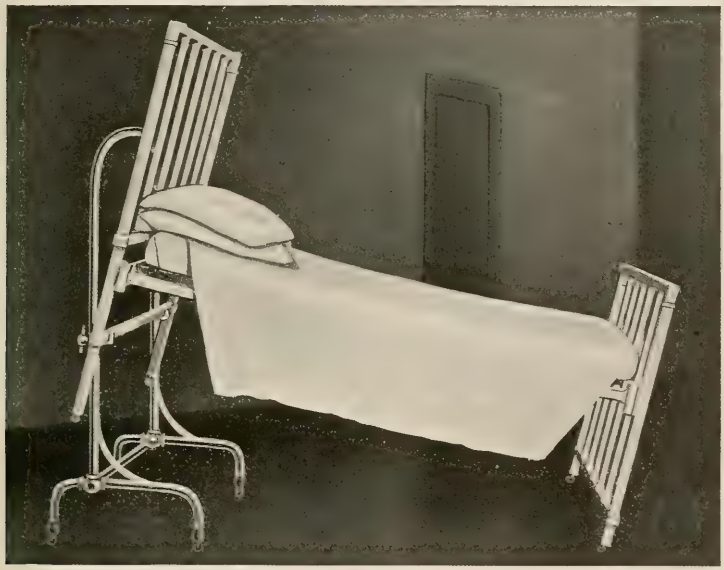


FIG. 7.—BED-LIFT FOR ELEVATING HEAD OR FOOT OF BED.
Showing hospital bed made up with mattress, sheet and pillow.

that it should be done. There are individuals, assistants, nurses, or friends of the patient, who should be found qualified to apply suggestion and exert a salutary influence upon the mind of the patient. It is often wise that such treatment be instituted before the patient comes under the administrations of the surgeon.

Every surgeon of large experience has had occasion to regret operating upon patients whose maladies in themselves were not serious but whose minds were full of fear and misgivings. I have frequently seen such patients do badly after an operation which should have been followed by recovery, dying in that peculiar state of depression which presents the appearances of a general failure of the glandular organs or of overirritability which we are prone to speak of as "shock." The physician now profits by these lessons and the surgeon should do the same. *The surgeon should not be so much concerned with the mechanics of his art and the local conditions to be dealt with as to neglect the nervous system of the patient.*

Another point to be borne in mind in treatment is that the sick person is not a normal person. Under the influence of physical discomfort, sepsis, anxiety concerning himself or his business, enforced confinement, and the mental influences incident to being not useful but, on the other hand, to being always served, he may become peevish, complaining or more exacting, than when well. He is prone to crave sympathy, to which end he exaggerates the degree of pain, or misrepresents the amount of sleep he has. The surgeon should give due consideration to these aberrations lest his judgment be influenced to the patient's harm. Above all they should be met by patience and kindly firmness on the part of all engaged in the care of the sick.

Resistance to Infection.—One of the most important conditions influencing the course of acute infective diseases is *leukocytosis*, *phagocytosis*, *antibody antagonism*, or more properly speaking the power, inherent in the cells and fluids of the body, of destroying invading bacteria. This *bacteriolysis* depends upon many conditions. The ptomains or excretions of the bacteria, being absorbed, cause the appearance in the body-fluids of certain materials, antagonistic to bacterial growth, called *opsonins*. The number of leukocytes in the blood is also increased. The opsonins impair the vitality of the bacteria, and permit them to be more easily enveloped and digested by the leukocytes which multiply at the site of the infection. Briefly we may say that the activity and efficiency of this process depend upon the vitality or good health of the patient. It becomes imperative, therefore, that in all conditions in which bacterial invasion of the tissues is to play any part, the bacteria-resisting power of the patient be brought to the highest possible state. Every one has this to a certain degree, but the virulence of an infection or the question of life or death is often decided by the resistance of the patient more than by the character of the infection.

The care of the whole patient is one of the prerequisites of surgical success. The surgeon is not alone responsible that a tumor shall have been removed, and patient and tumor safely transferred to separate parts of the hospital. The kidneys, damaged by the ether; the disturbances, incident to relaxation of the abdominal wall; the constipation, due to peritoneal adhesions; the neuralgia from nerve involvement in scar tissue—he should concern himself for all of these. In other words he should hold himself not responsible for a tumor but for an individual. Modern surgical treatment demands that the surgeon shall be of positive help to the patient, and that the patient shall be able to say not only that he had the operation done but that he is glad of it. A surgical success should not be consistent with the making of a physical wreck. The surgeon should follow up and know the after-history of his cases.

Finally, one of the most important principles of surgical treatment is that the surgeon should add to his technical surgical skill a scientific and humane interest in the whole of each patient who comes under his care. The function of the surgeon is not the performance of surgical operations—although this misconception is very prevalent—but it is the disposition and ability to do what is best for patients suffering with surgical diseases. This means the making or securing of an accurate diagnosis, and then the application of such treatment as he would want applied to himself, were he the patient instead of the surgeon. This is a simple rule, and easily remembered; sometimes it means operation, and sometimes not. Under all circumstances it is the one fundamental surgical principle which will stand the test of science.

ASEPSIS AND ANTISEPSIS

Asepsis and antisepsis have to deal with the fact that the chief hindrances to the healing of wounds are bacteria, and that most inflammations and infective diseases are due to these organisms. The most important feature of modern surgery is the prophylactic exclusion of bacteria from the tissues of the body.

Infection from Within the Body.—Bacteria finding access to the tissues of the body are conveyed to different parts by the blood-stream and through the intercellular spaces. There are certain places of entrance through which constitutional infections are most apt to take place. These are the glandular follicles of the intestine, the tonsils, the deep urethra, the vulva, the follicles of the skin, the teeth, and wounds of the surfaces of the body. Places which are prone to harbor slight abrasions admit bacteria to the tissues and to the circulation. These are the anal region, the mouth and the skin. Bacteria also gain entrance to the body by growing and multiplying in small surface pockets where they find nourishing pabulum, their ptomains causing ulceration or breaking down of the lining epithelium. Such conditions occur in gland follicles, in the accessory cavities of the nose, and through decayed teeth.

Stings and bites of insects, small pricks of the skin or mucous membranes, and infected foreign bodies, all carry infective material into the tissues. Niduses of infection thus established may exist for a long time, and organisms may be swept from one part of the body to another, and a state of internal infection indefinitely maintained.

Such internal infections may rarely be transmitted to wounds which otherwise would remain uninfected. The infections of wounds are usually immediate and from without. As a prophylactic it is important that these stomata of entrance receive attention. Infective arthritis, commonly called rheumatism, is an internal infection acquired through some of these channels, and can be prevented by proper attention to them.

Infection from Outside of the Body.—The infection of wounds can not be properly treated without a clear conception of the manner of entrance of bacteria. Bearing in mind that bacteria are distributed over nearly all of the objects in nature with which we come in contact, being also abundant in the particles of dust in the air, it is evident that their exclusion from wounds is difficult. The air over the ocean is quite free from bacteria; the air of the country contains but few; but city air is rich in microörganisms. However, the organisms in the air are usually harmless to wounds unless deposited in large numbers. Isolated bacteria falling into a wound usually perish.

This universality of bacteria causes the infection of practically all wounds. Whether the bacteria are to grow and multiply is determined by the resisting power of the tissues. If the bactericidal body-fluids and the white blood-cells overcome them, they are consumed and disappear. If they find pabulum in which they can grow, infection and inflammation are the result. Dead material in wounds, such as loose pieces of fascia, muscle or blood-clot, which have become separated from their vital connections, furnish culture media in which bacteria may multiply until their number and the

destructive power of their excretions are so great that the local resistance of the tissues is overcome and a destructive development of bacteria goes on.

What is called *infective inflammation* of wounds is simply the reaction of the tissues excited by the irritating presence of the bacteria and their products. It is characterized by an increase in the number of leukocytes in the circulation, by dilatation of the local blood-vessels, by extravasation of leukocytes and blood-serum, and by destruction of bacteria by the body fluids and white cells. This is a salutary process, and should not be hindered. It is the function of surgical art to bring to the aid of nature every help in her effort to overcome invading organisms. The warm *poultice* and the induction of artificial *hyperemia* both aid nature. The old-fashioned poultice of nonsterile material has the disadvantage that it can not be applied to an infected wound because the bacteria find protection for growth and evasion of the leukocytes in the warm material of the poultice, which thus may do more harm than good.

Wounds receive infection from the skin, which always harbors bacteria, not only upon its surface but also deep in its follicles from which they can not be removed by washing. A wound inflicted through the skin has these organisms carried into it.

The other sources of infection are the clothing, the instrument inflicting the wound, the hands, the air, the saliva projected from the mouth in conversation, and all surrounding unsterilized articles. Nature endeavors to shut out these from wounds by forming a scab, and then when the battle with those organisms which have entered is ended, the wound is sterile and protected. The surgeon aims to aid these natural processes.

The application of the principles of asepsis and antisepsis has to do with the exclusion of bacteria from wounds and the destruction of invading microörganisms. The first step in this direction is *cleanliness*. *Mechanical cleansing* with soap and water and other fat-dissolving agencies is applied to the skin in which operative wounds are to be made, and to the hands of the surgeon and assistants who are to touch either the wound or materials which are to come in contact with the wound. To this mechanical cleansing of the skin, is added chemical bactericidal treatment; with the view of reaching the bacteria in the skin follicles.

Sterilization of instruments and materials is accomplished by means of heat, chemicals, dehydration, oxidation, and light. *Heat*, either moist or dry, kills bacteria at temperatures varying with different organisms. Moist heat is used in the form of steam or boiling water. Dry heat is applied as hot air, the flame or heated metal. The spores of bacteria are more resistant than the organisms themselves. The temperature of boiling water, 100°C. (212°F.), destroys all known bacteria in a few seconds. Spores of some organisms require boiling for a considerable length of time. *Fractional sterilization* is resorted to to destroy spore life. This consists in the application of heat at 100°C. (212°F.) for fifteen or twenty minutes, and then keeping the material at a temperature between 21 and 32°C. (70 and 90°F.) for twenty-four hours to allow the spores to develop into bacteria. The boiling process is then repeated, and a third boiling is given at the end of another twenty-four hours. This practically eliminates the danger of spore development. A temperature of 66°C. (150°F.), suffices when fractional sterilization is practiced.

The common bacteria of suppuration are not spore-bearing organisms, and are easily destroyed by moderate degrees of heat. So effective is heat that it is employed almost exclusively in the sterilization of instruments, dressings and other materials for wound treatment.

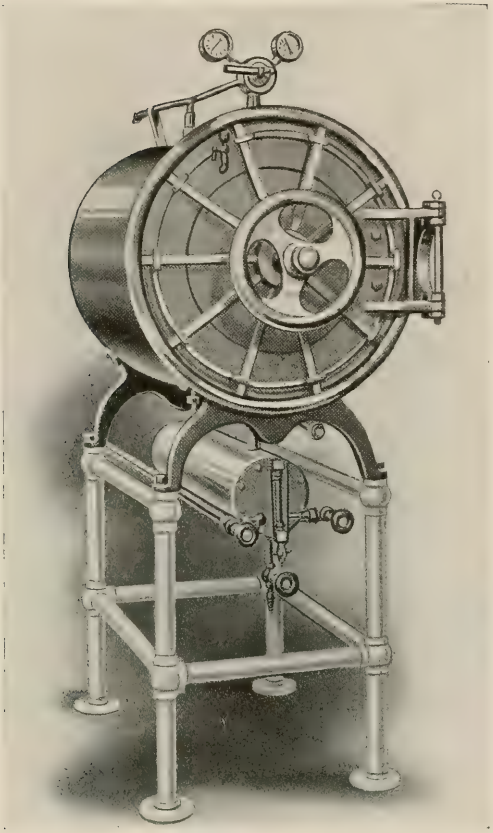


FIG. 8.—STEAM STERILIZER.
Sterilizes by means of live steam under pressure.

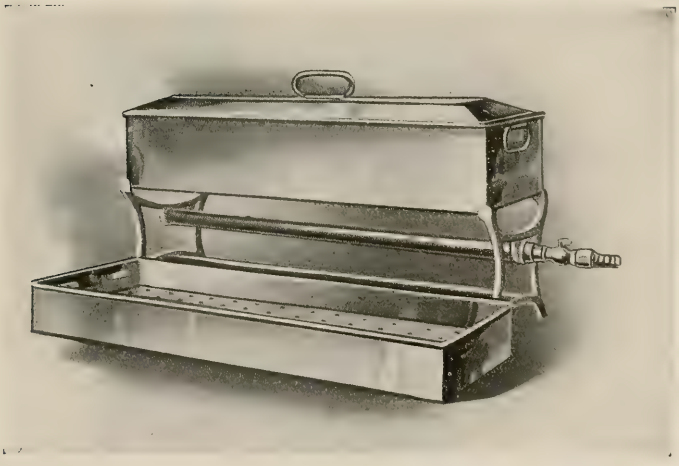


FIG. 9.—HOT-WATER STERILIZER FOR INSTRUMENTS.
Water is heated by gas flame. Heat may be supplied by electricity, steam coil or alcohol flame.

Certain bactericidal *chemicals* are used where heat can not be applied. There are also chemical agents which do not kill bacteria but which inhibit their growth. These are usually less poisonous and less irritating than bactericides and are much used in surgery.

The process of drying (dehydration) depends for its virtue upon the fact that bacteria require moisture for their growth. It does not destroy spores but it prevents their development into bacteria. In the absence of bactericidal heat dehydration may be employed in connection with the *sun's*

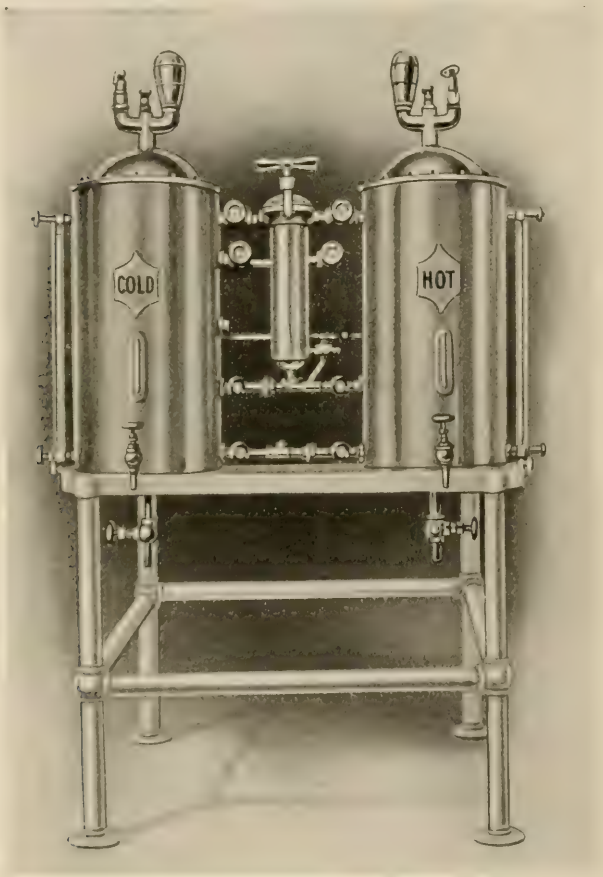


FIG. 10.—WATER STERILIZER.

Heat may be supplied by gas flame, steam coil or electricity. Water is filtered, sterilized and kept cold and hot.

rays and *oxidation* as antiseptic agents. The rays of the sun have a distinctly bactericidal action. Two most efficient disinfecting agents are fresh air and sunshine. Water may be sterilized by keeping it shaken up with air so that it may become thoroughly acted upon by oxygen. The water of a running brook is often quite free from bacteria, but bacteria grow in it when it comes to a standstill.

The *steam sterilizer* is the most useful apparatus for sterilizing by moist heat (Fig. 8). It is built in such a manner that steam is turned into its

interior under pressure. Dressings and fabrics to be sterilized are thus subjected to a temperature of about 116°C. (240°F.) at a pressure of 10 to 15 pounds or more to the square inch. This gives the advantage of moist heat, at a higher temperature than that of boiling water, and also pressure to drive the steam into the materials to be sterilized. The apparatus is provided with a steam jacket in which a still higher degree of heat can be maintained, thus preventing condensation and wetting of the dressings. If the materials and the inside of the sterilizer are heated before the steam is turned in and if the steam is allowed to escape and dry filtered air permitted to take its place before the apparatus is opened, the dressings come out practically dry. All of this is provided for in the apparatus now commonly in use.

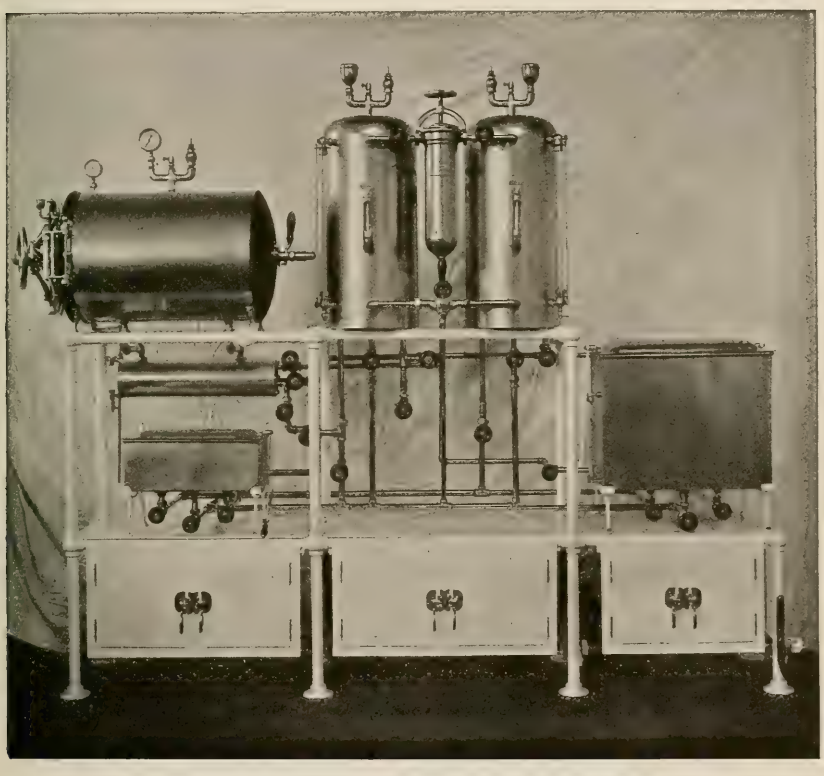


FIG. 11.—COMBINATION STERILIZING EQUIPMENT.

Dressing, water, utensil, and instrument sterilizers. Heat may be supplied by gas flame, electricity, or high-pressure steam. (*Keen's Surgery.*)

Besides the above described sterilizer, others are made on the principle of the steam cooker, which consists of a water receptacle below and shelves above, the whole being covered by a lid. The water being boiled, this gives an application of steam but not under pressure; and it has not so much to recommend it as simple boiling water. Such a sterilizer gives a temperature of 100°C. (212°F.) and is effective if used for a long time or if fractional sterilization is practiced. The ordinary wash boiler can be converted into such an apparatus for emergency use. Dry, or hot air, sterilizers are now little used.

Sterilizing by boiling water is the most effective of methods. It is applied

to instruments and all such materials as are not damaged by wetting. The apparatus is most simple and may consist only of a pan of water over a flame. The best sterilizer is heated by a steam coil lying under the water (Fig. 9). A resistance coil connected with an electric current is also used. Such sterilizers are provided with wire or perforated trays for lifting materials out of the water.

For the preparation of sterile water for operating room use sterilizing apparatus (Fig. 10) is made to supply water both hot and cold. Combinations of these various types of apparatus are in use (Fig. 11).

These are the general fundamental principles of asepsis and antisepsis. The technic of their application is described in the chapters treating of surgical materials and of wounds. Besides aseptic and antiseptic measures which are applied to bacteria from without there are constitutional treatments which may be administered and which increase the resistance of the body against certain microörganisms. This treatment consists in vaccination or inoculation of the patient with bacterial products which inhibit or check further bacterial growth. There are also certain drugs which have an inhibitive action on parasitic organisms in the body. These measures are described in the chapter on Surgical Infections and Fevers, and under the diseases in which they are employed. The hygiene of the patient, to increase his vital resistance, should be given attention by the surgeon in connection with the principles of asepsis and antisepsis.

SURGICAL MATERIALS, THEIR PREPARATION AND STERILIZATION

It is customary for the surgeon to keep on hand, ready sterilized and sealed from contamination, such suture material, dressings and other surgical necessities as can to advantage be so treated. Instruments are usually sterilized just before using although some instruments for emergency use may be kept sterilized and sealed.

LIGATURES AND SUTURES

Ligatures, for tying blood-vessels, and sutures, for closing wounds, are made of two classes of materials—*absorbable* and *non-absorbable*. The first of these is represented by catgut and tendon, the latter by silk or silver wire. The former possess the advantage that they become dissolved in the body-fluids and disappear. This sometimes is a disadvantage when softening occurs before healing together of the united parts has taken place. Non-absorbable materials are employed as removable and as non-removable. The former use is the more common. If left buried in the tissues they act as foreign bodies and may give no immediate disturbance, but sooner or later bacteria may become lodged in them and trouble develop. Fine silk is ultimately absorbed. Suture materials are made in many sizes (Fig. 12).

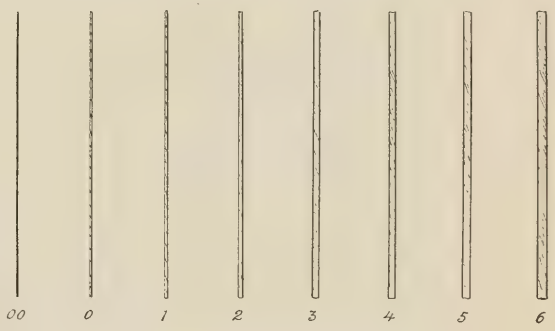


FIG. 12.—SURGICAL CATGUT.
Scale of sizes. (*Keen's Surgery.*)

The best and the most widely employed material for ligatures and sutures is catgut.

Catgut.—Catgut is made from the intestine of the sheep, and is twisted into threads or strands the size of which is designated by numbers (Fig. 13). That marked oo is the finest, and is suitable for very fine sutures and for tying small vessels. The next size is o, the next No. 1, and so on up to No. 6. The sizes o, 1 and 2 have the widest applicability. The larger sizes are employed for tying heavy pedicles or suturing bone. The origin of catgut makes its sterilization particularly important. It is known to be infected sometimes with *anthrax bacillus*, the spores of which are very resistant. Commercial catgut is dry and hard. That selected for surgical purposes should look clean. It should be even and strong. The best has a brownish-yellow color. It can not be sterilized in plain water, or kept in water because it swells and softens. Usually it is preserved in small covered jars containing one spool immersed in sterile alcohol. Before using, if it is desired to soften it, after threading on the needle, it may be moistened slightly with water.

There are many satisfactory methods of sterilization. Before being sterilized catgut should be freed of fat by washing it in ether or chloroform or immersing it for twenty-four or forty-eight hours. It should be loosely wound or simply twisted in strings or figure-of-eight bunches. The finer the catgut, the more easily and surely is it sterilized. For this reason when extra strong gut is required for ligating pedicles, etc., a most satisfactory plan is to braid together three strands of finer gut. This *braided catgut* also has the merit of being tied more securely.

Cumol Method.—Cumol is a hydrocarbon which is inflammable but not explosive. It boils at 170°C. (338°F.). The fat-free catgut should be suspended or laid on cotton in a glass beaker or test-tube and heated for two hours in an oven or on a sand bath at a temperature of 80°C. (176°F.). This

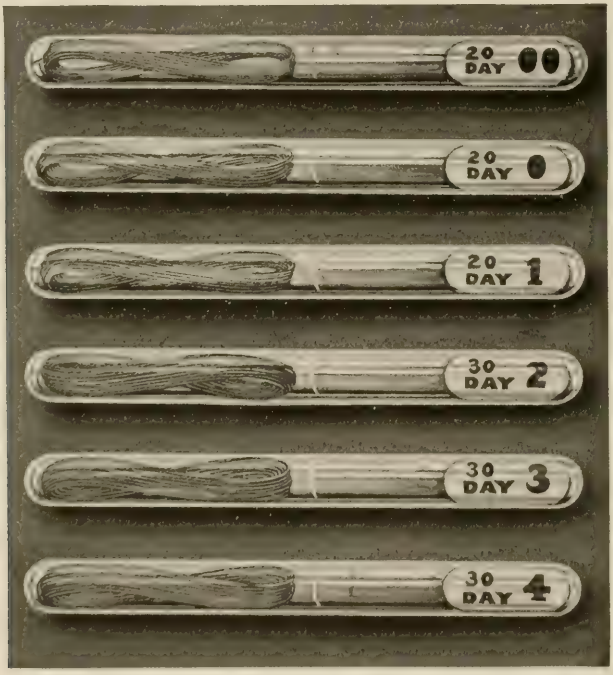


FIG. 13.—CATGUT, STERILIZED AND READY FOR USE, AS SUPPLIED IN SEALED GLASS TUBES.

heat drives out all moisture from the catgut. Cumol at a temperature of 100°C. (212°F.) is then poured in to cover the catgut and the temperature raised to 165°C. (329°F.). This temperature is maintained for one hour, at the end of which the cumol is poured off and the catgut dried by continuing the temperature at 100°C. (212°F.) for two hours. It is then preserved in sterile test-tubes or jars of sterilized alcohol.

Toluol Method.—Toluol is a light hydrocarbon, boiling at 111°C. (231.8°F.), and is not decomposed by heat, light, nor time. It will not hold water in solution, and is, therefore, very preferable to chloroform for storing catgut. It is a powerful solvent of oils and fats and, therefore, removes these substances from the catgut. It gives a clear luster to the gut amounting almost to transparency. It is not irritating to wounds, and is mildly antiseptic. Its value is chiefly for the purpose of storing catgut. The fluid

commonly used for this purpose has been chloroform. Toluol offers a material which possesses many advantages. The catgut may be placed in the toluol, sterilized by heat; and it is ready for use.

Iodin Method.—Raw catgut wound in single layers on spools is immersed for eight days in a solution of iodin, 1 part; potassium iodid, 1 part; distilled water, 100 parts. It is then rinsed off and preserved in alcohol. If preserved in the iodin solution it becomes too brittle for use after three or four months.

Better than iodized catgut, is catgut treated with *potassium mercuric iodide*, in 1:1000 alcoholic solution. The thread is immersed in the solution for seven days. As this solution is much more strongly germicidal than 1:100 iodin solution the gut is much more surely sterilized. The gut is then washed in alcohol, to remove the salt and put up in chloroform in tubes. The textile strength of gut is increased by treatment with this salt.

Ammonium Sulphate Method.—The gut is wound in one layer on spools. It is boiled for ten or thirty minutes in a saturated solution of sulphate of ammonium in water, or for ten minutes in a saturated ammonium sulphate solution containing, 1 to 2 per cent. of phenol. It is then rinsed in sterile water and preserved in alcohol.

Bichloride of Mercury Method.—Dried, fat-free catgut, wound in loose rings is placed in a solution of bichloride of mercury, 1 part; alcohol (95 per cent.), 500 parts. The smaller sizes should be left immersed for nine days, the larger sizes for fourteen days. From this it is transferred to alcohol for keeping.

A quick method is to immerse the gut in bichloride of mercury 1.2 Gm. (20 grains); tartaric acid, 6 Gm. (100 grains); alcohol (95 per cent.), 180 c.c. (6 ounces). Small sizes may be treated thus for seven minutes, and large sizes for half an hour. The gut should then be washed and preserved in alcohol (95 per cent.), to each 250 c.c. (8 ounces) of which is added one drop of a 3 per cent. solution of palladium chloride.

Alcohol Method.—Alcohol (97 per cent.), boils at a temperature of 84°C. (183°F.). The spores of bacteria are not killed by this temperature but the developed bacteria are. Moist heat at 54°C. (129°F.) destroys streptococci and anthrax bacilli within ten minutes. The spores of anthrax are killed by a temperature of 100°C. (212°F.) at the lowest. The principle of fractional sterilization must be employed if the sterilizing medium is boiling alcohol. The catgut is wound loosely upon glass spools, a strand to each spool, and placed in the ordinary glycerin-jelly jar of the pharmacist, filled with absolute alcohol. A number of these jars are placed in the inverted position in a one quart glass fruit jar and covered with absolute alcohol. The lids of all of these jars must be slightly loosened in order to allow the escape of expanding alcohol. The large jar is then placed in a water bath and the water boiled for half an hour. The lid of the jar is then screwed down tightly and the heat is withdrawn for twenty-four hours. At the end of that time the boiling is repeated for another half hour, and then another day allowed to elapse to permit spore development. After the third boiling the caps are screwed down tightly and the catgut may be set away ready for use. This results in the loss of a certain amount of alcohol from the larger vessel which must be added in order to keep the small jars covered. In preparing catgut in large quantities by this method the loss of alcohol is considerable and may be saved by adding a condenser to the apparatus. In place of a glass jar a strong copper cylinder may be used, the top of which can be screwed down so that the vapor of the alcohol does not escape, but is retained under pressure. By this means the temperature of the alcohol can be raised to that of the

boiling water in which it is immersed, and one boiling for an hour is all that is required.

Formalin Method.—Loosely wound fat-free catgut is soaked for from twelve to forty-eight hours in a 2 to 4 per cent. aqueous formaldehyd solution. The formalin is then removed by soaking for twenty-four hours in running water. The gut is then boiled in distilled water fifteen or thirty minutes and preserved in 4 parts of phenol to 100 parts of (96 per cent.) alcohol, to which 5 parts of glycerin have been added; or 1 part of bichloride of mercury may be substituted for the phenol. Another formalin method consists in subjecting the catgut directly to the action of formalin gas. Another method consists in immersing the catgut for twenty-four hours in a solution of equal parts formalin (40 per cent. sol.), alcohol, glycerin, and phenol. It is then washed and preserved in alcohol.

Formalin-Iodin Method.—Raw commercial catgut is immersed in a 4 per cent. aqueous formalin solution for thirty-six to forty-eight hours. It is next washed in running water, and then placed in a solution of iodin 1 part, potassium iodide 1 part, and distilled water 100 parts, for seven days. This gives strong, sterile catgut.

Argentized Catgut.—Catgut loosely wound upon glass spools or slabs is placed in a jar containing a 2 per cent. solution of collargolum. There should be only enough solution to immerse the catgut. It is left in this solution for a week. The solution should be shaken once or twice during this interval. At the end of this period it is washed in sterilized water until the excess of collargolum is removed, and preserved in 95 per cent. sterilized alcohol.

Dry Heat Method.—Fat-free catgut is wrapped, in separate strands, in paraffin paper and sealed in paper envelopes. The envelopes are placed in the sterilizer and subjected to a dry heat at 140°C. (284°F.) for an hour, and for three hours at 149°C. (300°F.) This should be done on two successive days. When used the gut may be rendered pliable by water.

Paraffin Method.—The catgut is coiled into loose bundles, each bundle containing one length of 75 cm. (30 inches). It is dried for one hour at a temperature of 82°C. (180°F.) and then for about forty-five minutes at 105°C. (220°F.). If the temperature goes above this the gut will be brittle. It is then placed in liquid paraffin where it remains for twelve to twenty-four hours or until it is clear. The paraffin containing the catgut is then placed in a sand bath and the temperature gradually elevated in the course of one or two hours to 160°C. (320°F.), and this temperature is continued for a second hour. This temperature should not be exceeded. The catgut is then lifted out of the paraffin and preserved in a 1 per cent. solution of iodin in methyl alcohol (97 to 98.5 per cent.). This is the method devised by Willard Bartlett.

Moist Heat Method.—Catgut that has been impregnated with a 4 per cent. solution of formaldehyd for fourteen or sixteen hours, and then rinsed in 5 per cent. ammonia water, can be boiled without injury for fifteen or twenty minutes just before using. While it is being boiled it must be held on the stretch, and for this purpose it should be strung on a frame long enough to hold the strands at full length. The threaded needles may be sterilized with the catgut.

Chromicized Catgut.—This is one of the most useful of suture materials. The treatment with chromic acid or its salts renders the gut less absorbable, and by regulating the length of time that it is left in the chromic solution, the absorption of the catgut in the tissues may be deferred for from two to six weeks. Previously sterilized catgut, rolled loosely on spools, is immersed

in alcohol (95 per cent.) for twenty-four hours. It is then thoroughly dried in a hot air oven, and placed in bichromate of potash 1 Gm. (15 grains) to 500 c.c. (1 pint) of water. Small sizes are left in this for forty-eight hours, and large sizes for fifty-two hours. It is then preserved in 95 per cent. alcohol. Or the gut may be chromicized in a 4 per cent. solution of chromic acid and then sterilized by the cumol method. Another method consists in placing 200 parts by weight of catgut, for twenty-four hours in a 2 per cent. phenol solution, 200 parts; water, 2000 parts; and chromic acid 1 part. Another method places fat-free catgut for twenty-four hours in a 4 per cent. aqueous solution of chromic acid. It is then dried in a hot-air oven and sterilized by one of the above described methods. Spools of catgut may be boiled from ten to thirty minutes in 1:1000 chromic acid solution saturated with ammonium sulphate. The spools are then rinsed for a minute in warm sterile water and preserved in alcohol.

The strength of the chromic acid solution, the thickness of the catgut, and the length of time of immersion determine the absorbability of the catgut. Thus by adjustment of the technic, catgut is produced which in the living tissues has a known power of resisting absorption. Such catgut is designated as "ten-day chromicized catgut," "twenty-day catgut," or whatever the index of absorption may be.

Tannic Acid Method.—This method uses tannic acid in the same manner as chromic acid or bichromate of potash is employed in preparing chromicized gut. By varying the strength of the tannic acid solution, the length of time required for absorption by the tissues of the *tanned catgut* may be varied from a few days to several weeks.

Kangaroo Tendon has greater strength and endurance than catgut. It is prepared from the tail tendon of the kangaroo, and may be sterilized the the same as catgut. If desired plain, it may be boiled for half an hour in albolin and preserved in absolute alcohol. Usually it is chromicized.

According to the method of H. O. Marcy, it is first soaked in a 1:1000 solution of bichloride of mercury. The individual strands are separated and dried. It is then chromicized and kept in a 5 per cent. solution of phenol in boiled linseed oil. Before using, the oil is wiped off and the tendon immersed for half an hour in 1:1000 aqueous bichloride solution. Kangaroo tendon does not swell and soften in water as catgut does.

Another method is as follows:—Soak in bichloride solution; separate strands; dry in a sterile towel; immerse in formaldehyd solution (2 to 4 per cent.) for forty-eight hours; wash in running water for twelve to twenty-four hours; immerse until a dark golden brown in chromic acid 1, phenol 200, water 4000; dry in sterile towel; and preserve in 10 per cent. phenolized oil. Before using wipe off in bichloride solution.

Crane, Heron and Reindeer Tendon.—These are prepared from the long leg-tendons of these animals. They may be sterilized by any of the above measures, but they are best adapted to the iodin method.

Silkworm-gut is obtained in strands about a foot long. It is smooth, clean and easily sterilized. It is non-absorbable, very strong, and makes an excellent material for deep through-and-through sutures. It does not absorb serum as silk does and hence is not penetrated by bacteria. It may be boiled for half an hour in plain water and preserved in alcohol or antiseptic aqueous solution or in the dry state.

Horsehair is obtained from the tail and mane of the horse. It is a fine suture, similar to silkworm-gut, but is more pliable and elastic. It is non-absorbable, and an admirable material for sewing small wounds of the skin. In its preparation, it should be washed with warm water and soap and cut

into 30-cm. (12-inch) lengths. It may be boiled or sterilized under steam pressure, and preserved in alcohol.

Silk thread, next to catgut, is the most valuable suture material. It is employed in all sizes. Black is the preferable color because it is most easily seen. Too much application of heat weakens it. The best means of sterilization are by steam. The silk should be wound on glass spools, and each spool placed in a small jar or test-tube, lightly plugged with cotton. A number of these jars may be put in a larger jar; and this placed in the steam sterilizer, and subjected to steam at 10 or 12 pounds pressure for thirty minutes. The process should be repeated at the end of twenty-four hours. The receptacles, containing the individual spools, are kept plugged until used. Spools which have been partly used may be resterilized. Sterilizing by moist heat tends to weaken silk.

Boiling in water for fifteen minutes is the simplest and surest method of sterilization. It weakens the thread more than the steam process; but, if the silk is not to be exposed a second time, a single boiling does no great harm. Silk may be kept dry or in a 5 per cent. phenol or in a 1:1000 bichlorid solution in alcohol.

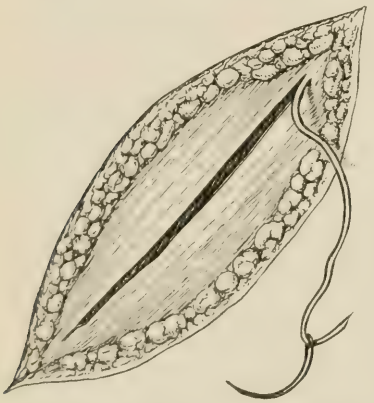


FIG. 14.—LIVING FASCIA USED AS SUTURE MATERIAL.

Paraffined Silk.—This is one of the most useful forms of silk. It is stronger than the ordinary silk, it does not fray, and is non-absorbable. It is prepared by winding silk thread loosely on glass bobbins, and soaking it for thirty minutes or more in white paraffin at a temperature not higher than 116°C. (240°F.). The excess of paraffin is then drained off and the silk sterilized by fractional sterilization in steam. To make silk still more stiff it may be sterilized first and then immersed in sterilized paraffin

Living Fascia.—In operating aseptically in the presence of strong fascia the surgeon may split off a strand of this living tissue, thread it through the eye of a needle, and employ it for suture purposes. This can be done most satisfactorily in operations for inguinal hernia; but may be practised in other parts of the body (Fig. 14).

The above are the suture materials of animal origin. Besides these, both vegetable and mineral sutures are used.

Linen is used much the same as silk. It has the disadvantage that it frays more. In the finer sizes it is not so useful as silk. In the larger sizes it is stronger. *Paraffined linen* is prepared the same as paraffined silk. It is better than silk for the subcuticular suture as it is stronger and stiffer.

Celluloided linen is prepared by boiling linen thread in a 1 per cent. solution of carbonate of sodium; this is wrapped in a sterile cloth and dried in the oven; it is then immersed in a solution of celluloid heated in a hot-air sterilizer; after which it is wound and kept in a dry receptacle. It may be sterilized by boiling in carbonate of sodium solution.

Wire.—*Silver* and *bronze wire* are most commonly employed in surgery; but *iron wire*, which can be bought at any hardware store, answers every purpose, and is stronger and cheaper. *Aluminum bronze*, if fine enough, has the advantage that it is ultimately dissolved and disappears. Wire is sterilized by boiling. Wire may also be sterilized by heating it in the flame, which has the advantage that it anneals the metal and renders it less liable to break when being twisted.

DRESSING MATERIALS

Dressing materials are used to protect wounds from mechanical damage, to prevent infection, to absorb discharges and by pressure to prevent hemorrhage and act as splints to immobilize wounds. Almost every absorbent material in nature has been employed for these purposes. The chief essentials are that it shall be absorbent, non-irritating, sterilizable and plentiful. At present the most commonly employed materials are gauze and cotton.

Gauze.—Gauze is loosely woven cotton cloth, also known as cheese cloth or mull. It appears in commerce in bolts, 1 meter (1 yard) wide and in both the bleached and unbleached condition. It is the cheapest cotton fabric made, and at the same time the best for the surgeon's use. The bleached gauze is quite free from dirt and oil, and usually requires no treatment further than sterilization. The unbleached cheese cloth may be rendered absorbent by boiling with soft soap or carbonate of soda, followed by prolonged rinsing in clean water and drying. For convenience, gauze may be cut into 1-meter (1-yard)lengths, making squares which can be folded in such a way that the raw edge is turned in and, therefore, does not precipitate loose threads. Or it may be rolled into bandage-like strips. These squares are also called compresses or handkerchiefs.

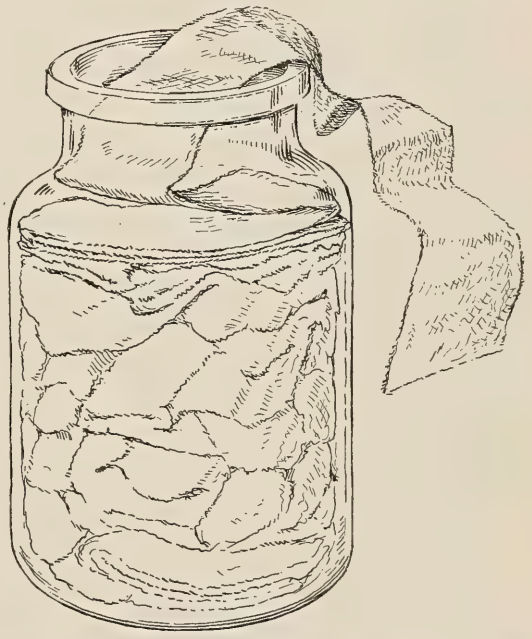


FIG. 15.—GAUZE FOLDED IN RETAINER SO AS TO BE EASILY STERILIZABLE AND REMOVABLE.

To sterilize gauze, the compresses are wrapped in packages, five or ten in a package, covered with a towel or muslin wrapper, and placed in the steam sterilizer under 12 or 15 pounds pressure at 120°C. (250°F.), for twenty minutes or more. Or they may be sterilized in a jar or other covered receptacel. The ordinary glass fruit jar answers admirably for this purpose, the top being left off or loosely adjusted during the sterilization and then screwed down. In the hospital, where much gauze is used, it is customary to keep a supply sterilized and ready for use. Where a little gauze is required in the surgeon's practice it may be sterilized by boiling. In the hospital where large quantities of gauze are used economy demands that gauze which has been used for dressing and sponge purposes, if not too much soiled, shall be washed, resterilized, and used again. The old practice of immersing gauze in an antiseptic solution, while useful in an emergency, and better than nothing, can not be depended upon to accomplish sterilization.

Medicated gauze is gauze which has been impregnated with some chemical substance which keeps the gauze sterile, which it is desired to convey into

wounds, or which has some special therapeutic value. The gauze for purposes of packing into wounds or cavities is best prepared in strips about 8 cm. (3½ inches) wide. These strips should be laid in sterile containers not rolled, but folded so that when wanted they can be drawn out easily (Fig. 15).

Chlorinated gauze is made by impregnating gauze with sodium hypochlorite solution (0.5 per cent.). It must be freshly prepared (see Antiseptics, page 61).

Bichloride gauze is prepared by wringing out sterilized gauze in a solution composed of bichloride of mercury, 10; sodium chloride, 240; citric acid, 480; glycerin, 3500; water, 15,000. This is enough for 60 meters of gauze. The citric acid and sodium chloride prevent decomposition of the mercuric bichloride. The gauze is put away moist in covered sterile jars, or gauze may be soaked in bichloride solution and permitted to dry. What is still better, is to prepare it when it is wanted, by immersing sterile gauze in the desired solution and using it moist.

Iodoform Gauze.—The efficiency of this material depends upon the liberation of iodin under the influence of the warmth and moisture of the body. Iodoform in the dry state is capable of retaining bacteria. It is necessary that it should be sterilized. When moist it is decomposed by heat. The sterilization of iodoform gauze is accomplished by mixing with some antiseptic or by exposing to formaldehyde.

The gauze is prepared as follows:—Soak sterilized gauze in 1:1000 aqueous bichloride solution. Under aseptic precautions, with gloved hands, unfold this in a mixture of iodoform, 1 part; glycerin, 2 parts; and 1:1000 aqueous bichloride solution, 32 parts. The gauze should have this mixture worked through its meshes until it is thoroughly impregnated; it should be lightly pressed to remove the excess, laid in folds in its receptacle, and covered. These proportions make a 3 per cent. mixture. Six or 10 per cent. iodoform gauze is made by using one-half or one-third of the above amount of bichloride solution. The glycerin serves to hold the iodoform in the water; it also prevents the gauze from becoming dry and hard after the evaporation of the water. The amount of glycerin may be increased if the gauze is to be kept for a longer time. *Sticky iodoform gauze* which will adhere to the tissues is made by wringing out gauze in a mixture of 100 Gm. of resin, 50 Gm. of glycerin, and 1200 Gm. of alcohol; and, after the gauze has become somewhat dried, rubbing in 230 Gm. of iodoform to every 6 meters of gauze. *Iodoform wicking*, used for drainage, is impregnated the same as gauze.

Phenol gauze is made by wringing out sterile gauze in phenol ("Carbolic acid"), 3 parts; glycerin, 19 parts; distilled water, 32 parts. This is preserved in sterilized, glass-covered retainers. Or for immediate use gauze may be moistened with the desired strength of phenol solution. *Balsam-of-Peru gauze* is prepared by impregnating gauze with balsam of Peru which has been sterilized by heat in the steam sterilizer or water bath. The wound-stimulating property of the balsam may be increased by mixing with it 5 per cent. of naphthalin powder.

Bismuth gauze is made with subnitrate, subgallate, or subcarbonate of bismuth. It is made with 60 Gm. (2 ounces) of bismuth salt, 60 Gm. (2 ounces) of glycerin and 1000 c.c. (1 quart) of water. The bismuth and glycerin are mixed, and warm water is then slowly added while the mixture is stirred. A piece of gauze 20 meters long is passed through this emulsion three times, gently squeezed to remove excess of fluid, and the water allowed to evaporate. It is then cut in strips, folded into jars, and sterilized by steam at 8 or 10 pounds pressure for thirty minutes. This gauze may be used instead of iodoform gauze for all purposes except that of deodorization.

Adrenalin gauze is made in narrow widths for use in small cavities such as tooth sockets, and accessory nasal sinuses. The fabric is impregnated with adrenalin chloride solution 1 : 2000.

Chloretone gauze is made by impregnating the fabric with 10 per cent. chloretone solution. It is used in painful and irritable wound cavities and surfaces. Chloretone (acetone-chloroform) is antiseptic and sedative.

Chlorazene gauze is similar to chlorinated gauze (see page 60).

Zinc oxide gauze is made by immersing sterilized gauze strips in a mixture of zinc oxide powder, 1 part; glycerin, 2 parts; and water, 16 parts. The excess of mixture is squeezed out, the gauze loosely folded in glass jars, and sterilized in the steam chamber.

Boric acid gauze is made by boiling gauze in a saturated solution of boric acid and permitting it to dry.

Boro-salicylic gauze is prepared by boiling the gauze in 3 parts salicylic acid, 30 parts boric acid, and 1000 parts water. This is called *Thiersch's solution.*

Kephalin gauze is prepared by dissolving kephalin (macerated brain extract) in ether. A 5 per cent. solution is made, and poured over strips of gauze bandage about 10 cm. (4 inches) wide. The ether is allowed to evaporate, the gauze is folded in layers, wrapped in muslin, and sterilized in the steam autoclave for ten minutes at a temperature of 120°C. (248°F). It has marked hemostatic properties.

Paraffined gauze is prepared by impregnating the fabric with liquid petrolatum. Cotton sponges when covered with such gauze are more absorbent than when covered with plain gauze. When the fabric is soaked in liquid paraffin which is solid at ordinary temperature, it is not so useful an absorbent, but is valuable for wound dressing purposes because it is thus rendered less adherent.

Cotton.—Cotton wool, next to gauze, is the most commonly employed dressing material. It is used as a supplemental covering to the gauze dressing, chiefly in the interest of economy. It is also used for padding purposes in the application of splints. It should not be put next to the skin as it absorbs, discharges poorly and becomes packed down and macerates the skin. When a cotton padding next to the skin is desired, the cotton should be separated from the skin by a few layers of cotton cloth, and if it is to be left on for a longer time than a week it should be well powdered with some drying powder. The cotton is found in the shops in rolls which can be unrolled into layers. The unbleached variety answers all surgical purposes excepting that of absorption. It is sterilized by dividing the ordinary pound "bat" into 4 parts, wrapping each in thin muslin, and sterilizing in the steam chamber. Cotton which has been washed and bleached is called *absorbent cotton. Surgeons* do not apply it next to wounds because it flattens out and becomes non-absorbent, making a nasty mass in which suppuration is encouraged, and fibres of which are left sticking to the wound. It is also little used by surgeons for sponging purposes as other materials are much better. The cheaper unbleached cotton is just as good for padding purposes and for covering gauze dressings.

Flax or tow is prepared and used the same as cotton. It is of value as an outer layer of dressing.

Oakum is flaxen or hempen fibre impregnated with tar. It is used as a covering for gauze dressings. It possesses the advantages that it is a good absorbent, firm and elastic; and it is slightly antiseptic on account of the tar which it contains, thus remaining sweet when contaminated with discharges.

Jute or Indian hemp is a vegetable fibre which is coarser than cotton but absorbent and possesses the advantage that it is elastic and does not collapse easily. When sterilized or impregnated with antiseptic it becomes an admirable outer dressing.

Paper wool is composed of thin strips of paper about 3 m.m. (⅛ inch) wide. This is a light, cheap, absorbent and can be made into little packages covered with gauze. It takes up discharges very readily, and is an admirable dressing.

Lamb's wool, washed and sterilized, tied about with a cotton string in appropriate sizes is used for tampons.

Wood-wool is composed of fine wooden shavings which have been macerated in water and rubbed through a sieve. It is a light, fluffy material which may be used as a dressing when encased in gauze bags. It becomes soggy and collapses like paper wool when wet with discharges.

Wood wadding is a substance made in the process of paper making. It is a cheap cellulose absorbent.

Wood fibre is made of pine needles and serves as a good dressing when covered with gauze.

Sawdust of pine wood is one of the cheapest and best absorbents. It can be put in bags or pads made of gauze or muslin of sufficient fineness of mesh to prevent escape of the contents. Such pads may be quilted to make them keep their shape. This dressing is as absorbent as any of the above described materials. It collapses or packs down less than any of them. It is the best dressing material known where pressure and absorption are desired at the same time, as in the treatment of chronic ulcer of the leg.

Turf-moss, used in surgery, is dried and cleaned *sphagnum cymbifolium,* which is very absorbent, firm and elastic and one of the best of dressing materials. It may be used as an outer dressing or wrapped in gauze and applied directly to the wound.

Florida moss is one of the mosses which has long hair-like branches and fluffy leaves and lends itself well for dressing purposes.

Peat is of service as dressing material after it has been washed.

Asbestos absorbent wool is a useful absorbent for wound dressings. It may be sterilized by any form of heat. It is practically indestructible, and is especially useful in regions remote from sources of supplies.

Charcoal was used as a wound dressing before the antiseptic era. When placed in muslin bags it becomes a dressing material of great absorbent power, which does not collapse and which remains sweet, when impregnated with discharges, better than any other material.

Coal Ashes.—Light, finely sieved, anthracite coal ashes are another material, possessing many of the advantages of charcoal. It is sieved in muslin bags of sufficiently fine mesh to prevent its escape. It is surprisingly absorbent and seems particularly adapted to the taking up of offensive discharges. The pads conform to the parts and serve as a splint. It is neutral in reaction. It does not take up thick gummy discharges well.

SPONGES AND PADS

Sponges.—For sponging up blood and wound discharges the material most employed is gauze. It is customary to throw away small pieces of gauze after one using. Larger pieces and pads are washed, resterilized and used again. For different wound purposes different shapes and sizes of sponges are employed.

Sea sponges are the most absorbent material used for sponging purposes.

They have been almost entirely superseded by gauze. They are more expensive than gauze and their sterilization is more difficult because a few sterilizations by heat destroy them. Sea sponges are prepared as follows: Firm fine sponges are selected and beaten with a wooden mallet to remove shells and coarse dirt. They are then soaked for two days in a 15 per cent. solution of hydrochloric acid, or for twelve hours in a 33 per cent. solution. Calcareous material is thus destroyed and the sponge bleached. They are next washed in running water until clean; and then immersed for fifteen minutes in a saturated (1 : 18) solution of permanganate of potash, or for an hour in a 1 : 100 solution. The sponges are then squeezed and placed in a warm saturated solution of oxalic acid until all of the color of the permanganate of potash has disappeared. The hands being covered with sterile rubber gloves, the sponges are next rinsed in sterile water. They are then kept in 1 : 1000 bichloride solution for a day, again rinsed in sterile water, and preserved in 5 per cent. phenol solution. In place of the treatment with permanganate and oxalic acid, the sponges may be soaked for three or four days in 5 per cent. green soap in water and washed in running water. They should be immersed in antiseptic solution for at least seven days before being used. At the time of operation they are rinsed out in sterile water, and after being soiled with blood, in clean wounds are rinsed

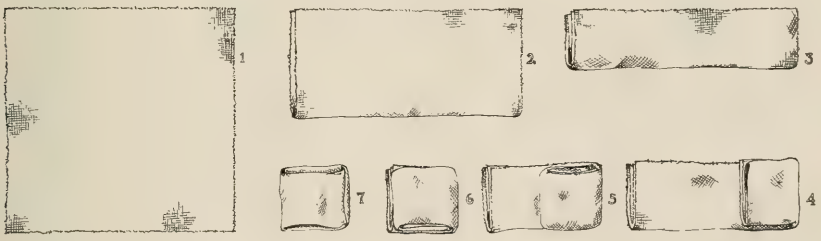


FIG. 16.—FOLDING GAUZE SPONGES.

1, Square of gauze 30 cm. × 30 cm.; 2, doubled; 3, quadrupled; 4, folded laterally; 5, folded again; 6, sixteen thicknesses; 7, rolled twice inside out—all raw edges have disappeared.

and used again and again. At the end of the operation they are washed in a solution of washing soda (1 : 30) and rinsed in sterile water.

Such sponges should not be used in a second case without sterilization by heat or dry sterilization with iodin or some other penetrating antiseptic. They may rarely be used in place of gauze sponges.

Gauze sponges are made for convenience in several sizes. *Hand sponges* are made of pieces of gauze 30 to 45 cm. (12 to 18 inches) square. Small sponges are of gauze 10 cm. (4 inches) square. In order to eliminate the frayed edges of the gauze and make a good absorbing mass the gauze should be folded upon itself several times. A satisfactory method for making small hand sponges is as follows:

Pieces of gauze are cut 30 cm. (12 inches) square (Fig. 16, No. 1). Each piece is folded lengthwise (2) once, and then again (3), thus producing four thicknesses. It is then folded at right angles to the first folds one-fourth of the distance (4) and again one-fourth (5) and again one-fourth (6). It is then taken in the right hand; the tubular opening in the free end is held open by the fingers of the left hand, and the whole mass inverted as is done with a pair of stockings in the domestic economy. This inversion is done twice and results in a turning in of the free edge until it disappears. This produces a thick sponge mass (7).

In another method of folding sponges a piece of gauze 30 cm. (12 inches) square is used. One edge is folded a trifle more than two-thirds of the distance across the square; the opposite edge is folded over this; the two other short sides are then folded toward one another in a similar manner, the end of one being tucked into the other between its folds. This leaves exposed one raw edge, which is eliminated by turning the outside in as above until the frayed edge is folded in and covered. This produces a flat sponge.

The larger squares may be converted into edge-free sponge masses by folding each corner to the center, thus making a square one-half the size of the original gauze; this is then proceeded with as above, the operation stopping short of the stocking-roll step.

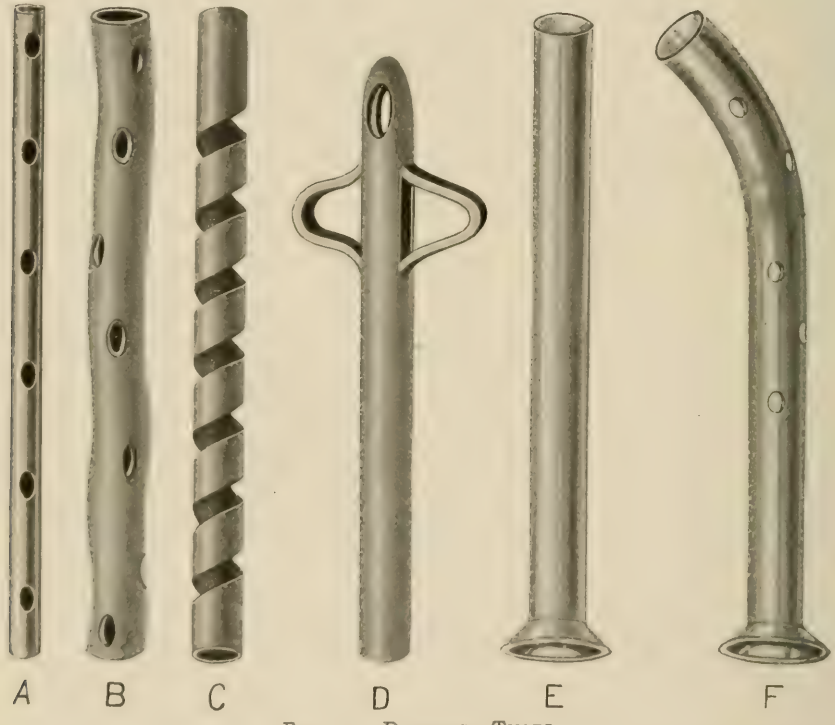


FIG. 17.—DRAINAGE TUBES.

A, *B*, *C*, Rubber drainage tubes; *D*, self-retaining rubber drainage tube; *E* and *F*, glass drainage tubes.

Stick sponges, sponges on holders, and smaller sponges for special purposes, may be similarly folded. These may be used in the special holders made for the purpose or in hemostatic clamps or ring forceps.

Sponges are also made by enclosing a dossil of absorbent cotton in gauze. For sterilization, sponges should be put up in muslin-wrapped packages of ten, twenty or fifty, and sterilized under steam pressure. Gauze sponges may be sterilized also by boiling.

Flat sponges, commonly called *laparotomy* or *abdominal sponges*, are used to cover and hold back coils of intestine in abdominal operations. They are made of five layers of muslin 20 or 30 cm. (8 or 12 inches) square, sewed together at the edges and having a tape 30 cm. (12 inches) long, sewed to one corner to prevent the disappearance of the sponge in the

abdomen. These sponges should be put up in bundles of ten, each marked with a number, in order that after each operation they may all be systematically accounted for. Besides gauze and muslin, flat sponges may be made of thicker cloth.

DRAINAGE MATERIALS

For drainage, anything that is aseptic and capillary or tubular may be used to keep a wound open and facilitate the escape of discharges. Gauze or a few strands of catgut, horsehair or other suture material serve for temporary drainage. For more permanent and effective drainage tubes are used.

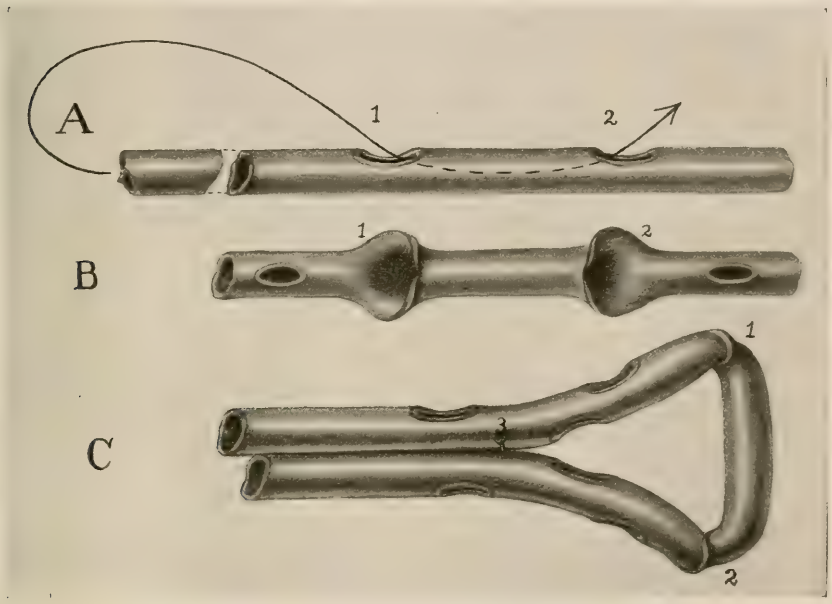


FIG. 18.—SELF-RETAINING RUBBER DRAINAGE TUBE.

Holes 1 and 2 are cut in a piece of soft rubber tubing (*A*). The end of the tubing (*A*) is passed in the hole 1 and out of the hole 2. This inverts the portion of the tube between the two holes, as shown in *B*. Other holes for drainage are then cut in the tube, the two ends are brought together and held at 3 with a stitch. Additional openings may be cut if desired. (*From Jour. Am. Med. Assoc.*)

Drainage tubes are made of several different materials. Rubber lends itself best for this purpose. *Rubber drainage tubes* are used in all sizes. The thickness of the tubing should be sufficient to prevent collapsing. They should be from 0.6 to 1.25 cm. (¼ to ½ inch) in diameter. In order to facilitate the entrance of secretions, fenestra are cut with scissors at suitable intervals. The deep end of the tube may be cut obliquely so as to enter the wound more easily (Fig. 17). Tubes about 15 or 20 cm. (6 or 8 inches) long are usually kept on hand. Rubber tubing should be scrubbed with soap and warm water, boiled for twenty or thirty minutes in 1 per cent. carbonate of soda solution, and preserved in sterilized alcohol, phenol or bichloride solution. Rubber tubes may be hardened by placing them for five minutes in sulphuric acid, then washing in clear water. Red rubber is best for this purpose.

While it is always convenient to have drainage tubes prepared and ready

fenestrated, my own preference is to have plain tubing in several sizes sterilized as above and kept in a large jar of 1:40 phenol solution. Just before using, the desired length of the desired size is called for, a nurse brings the opened jar to the instrument nurse, who, with sterile forceps and scissors picks up the end of the tube wanted, cuts off the length called for and hands it to the first assistant, who fenestrates it and hands it to the surgeon. The watery solution in which tubes are kept should be changed every week or two.

Drainage tubes of *glass* and metal are also employed. These receive no special preparation but are simply sterilized by boiling along with the instruments.

Glass tubing has the advantages of being non-collapsible and clean. It permits aspiration by a rubber tube inserted through it to the bottom of

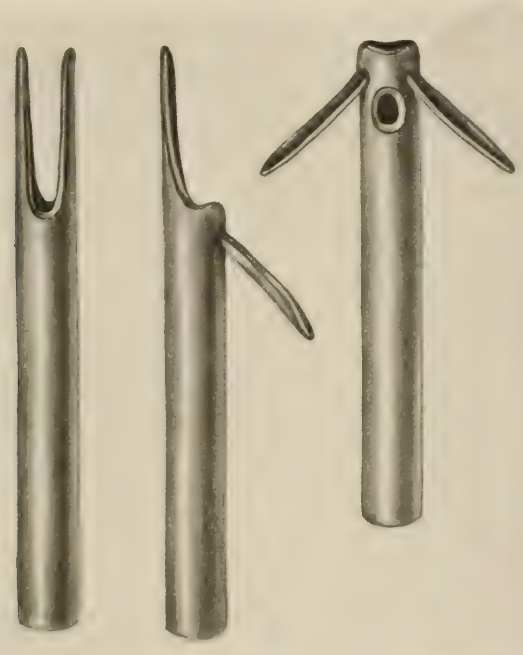


FIG. 18*a*.—SELF-RETAINING DRAINAGE TUBES.
Preparation of tubes to produce two arms which serve to prevent the tube slipping out of the cavity in which it is placed.

the wound and connected to a syringe. It also allows of supplementary capillary drainage by means of a strip of gauze or wick passed to its bottom, and which may be changed as often as is desired without disturbing the wound.

Self-retaining drainage tubes are made of rubber, glass and other materials flanged or enlarged in some way at the deep end to cause retention in the cavity in which they are introduced. Such tubes are used in the pleural cavity, bladder and uterus. An L or T end or other shape may be made on a rubber tube by drawing an end of the tube through a hole, cut near the end (Fig. 18). Commonly, tubes are retained by taking a stitch in the end and making it fast to the lip of the wound.

Drainage tubes may be made self-retaining by cutting the end of the tube in such a manner as to make a two-armed fork. A hole is cut into the tube at

the base of each arm, and the arm drawn back through the hole (Figs. 18*a* and 18*b*). (This device of Harrison's is well described in Fowler's Surgery, 1907; and in Surg., Gyn. and Obs., Jan., 1916.)

Gauze drains are made by cutting gauze strips 3 meters long and 5 to 15 cm. (2 to 6 inches) wide, and removing the loose threads at the cut edges or hemming the edges. Such drains may be sterilized or impregnated with medicament and kept in retainers (see Medicated Gauze). A controlled drain is made by pressing a square of gauze into the wound and packing its inside with gauze strips, the ends of which, together with the corners of the square, are left projecting from the wound.

Wick drains are cords of candle wicking which may be cut in meter lengths and treated as gauze drains.

FIG. 18*b*.—PREPARATION OF SELF-RETAINING DRAINAGE TUBE.
Each arm is pulled through a hole in the side of the tube.

Cigarette drains (Fig. 19) are rolls of wicking or gauze encased in rubber tissue which may be held together by sewing or by slightly moistening the edge with chloroform which causes it to stick. If gutta-percha is used the edges may be sealed by cement. The gauze must project beyond the rubber at the ends to get the best results, and the ingress of fluids may be aided by cutting holes at intervals in the rubber casing. This drain has strong capillarity, and has the advantage that it can easily be removed because of the absence of adhesions.

Non-absorbent Drains.—A good non-adhering drain can be made of *rubber dam*, folded or loosely rolled. Strands of suture material, such as

catgut, silk, silkworm-gut, and *horsehair,* are all employed where a short capillary drain is desired.

SURGICAL ACCESSORIES

Towels for use in surgery are made of ordinary dish toweling of the best quality. They should measure at least 50 by 75 cm. (20 by 30 inches), and have no raw edges. They are folded into packages of five to ten, covered with a muslin wrapper and sterilized under steam pressure.

Protectors, or sheets for covering patients during operations, should be made of good quality unbleached muslin. These sheets are constructed with the view of covering everything on the operating table except the field of operation and the face of the patient. At least two sizes are desirable for operating-room work: one size, 1½ meters square; the other ¾ meter wide and 1½ meters long. A large sheet, called an *abdominal sheet,* is made for abdominal operations. It has an elliptical opening 30 cm. (12 inches)

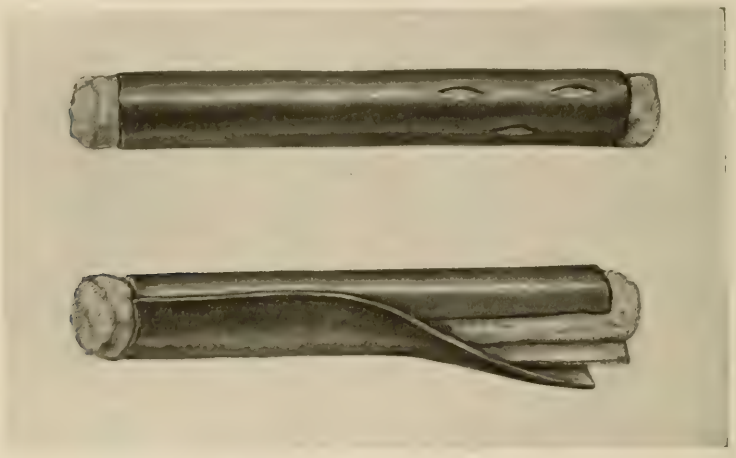


FIG. 19.—CIGARETTE DRAINS.
A roll of gauze enveloped in rubber tissue.

long and 15 cm. (6 inches) wide, ¾ meter from the upper end, through which abdominal operations can be done. This sheet may also be used for operations in the region of the perineum.

Perineal protectors for operations in the region of the vulva, vagina, perineum and anus, are made of two thicknesses of toweling, 25 by 50 cm. (10 by 20 inches), divided down the middle by a split 36 cm. (14 inches) long. All edges are sewed. The field of operation is exposed through the lower end of the slit, the two legs of the protector lying on the abdomen to hold it in place.

Blankets for covering patients in the operating room should be one-half the size of the ordinary single blanket. Quarter blankets are also useful for covering the chest. They should be sterilized by steam heat after being washed.

Operation Stockings and covers for the patients' legs are made of soft cotton flannel with draw-strings at the tops. They should be made to cover the foot and leg to the upper part of the thigh.

Operation jackets are made of the same material, tied with three tapes behind, extending to the middle of the thighs, and having loose sleeves.

Split retractors, to retract the soft parts in amputations, are made of towels or four thicknesses of unbleached muslin, 50 cm. (20 inches) long and 20 cm. (8 inches) wide, split once for the thigh and upper arm and twice for the forearm (Fig. 20).

T-bandages are made by sewing bound strips of unbleached muslin together, one strip to pass round the waist and the other to pass from the

FIG. 20.—SPLIT RETRACTORS, USED ESPECIALLY IN AMPUTATIONS.

middle of the back, under the perineum, to be fastened in front, for the purpose of retaining perineal dressings. A double T-bandage is also useful for the same purpose (see Bandages, Vol. III).

A triangular bandage for holding dressings to the perineal and sacral regions is made by inserting a triangle at the junction of the arms of the T (see Bandages, Vol. III).

Slings are made of unbleached muslin. One square yard cut diagonally makes two slings. The *triangle* thus made has many uses. For bandaging purposes it may be made of gauze.

Breast binders are made of strong unbleached muslin for retaining dressings on the breast. They are made to pin in front and with straps over the

shoulders. A medium size is 105 cm. (42 inches) long, 38 cm. (15 inches) wide in the back, 28 cm. (11 inches) wide in front, and 23 cm. (9 inches) wide in the axillary line (see Bandages, Vol. III).

Abdominal binders are made of strong unbleached muslin or of two thicknesses of medium weight muslin. They may be made in widths from 30 to 45 cm. (12 to 18 inches), and in lengths from 60 to 135 cm. (24 to 54 inches).

Caps for covering the heads of the surgeon, assistants and nurses are made of white muslin. The object of these caps is to cover the hair to

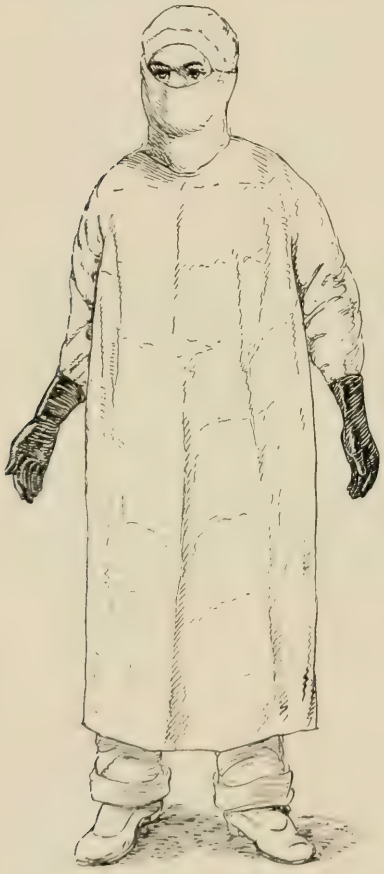


FIG. 21.—SURGEON'S OPERATING GARB.

FIG. 22.—NURSE'S OPERATING GARB.

prevent particles of dirt from falling upon sterilized materials and finding entrance into the wound. So long as they serve this purpose they should be made with as much consideration to simplicity and the esthetic as possible (Fig. 21). Nurses' caps should be made fuller and in such as manner as to cover the loose back hair (Fig. 22). Caps for patients should be made of unbleached muslin, because it is softer, and more durable. They should be provided with a shirr-string (Fig. 23).

Masks to prevent contamination from saliva projected from the mouth in speaking, are made of bleached muslin, 25 cm. (10 inches) by 15 cm. (6

inches) in size, and have a tape shirr-string run through the hem of the two long sides. The tapes are tied behind the head, the upper one passing above the ears. Larger masks may be made for surgeons having beards.

Operating suits for the surgeon are made of white drilling, duck or linen. The ordinary mechanic's suit of overalls, consisting of a jacket and trousers with suspenders, answers very well. Tapes for tying are better than buttons. Some surgeons prefer a longer upper garment reaching to the knees or lower. Others use a gown with long sleeves (Fig. 21). These garments should be loosely folded, wrapped in a square of muslin, designated

FIG. 23.—PATIENT DRESSED FOR OPERATION.

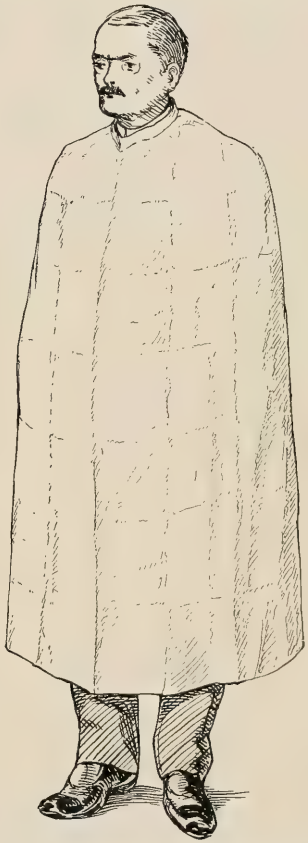


FIG. 24.—SPECTATOR'S GOWN OF UNBLEACHED MUSLIN.

in some way with a description of the contents, and sterilized under steam pressure. **Nurses gowns** should be the most simple, one-piece garment, of linen or drilling, buttoning behind or tied with tapes, or double-breasted and buttoning in front (Fig. 22). They should be sterilized the same as surgeons' suits. Visitors at operations should be provided with a simple cape of muslin (Fig. 24).

The resterilization of towels, sheets, protectors, caps and gowns, is accomplished by soaking for several hours in *cold* water to dissolve blood and pus; they are then rinsed in several changes of cold water, boiled in soap and soda for thirty minutes or an hour, rinsed in plain water, dipped in

blueing, wrung out, dried, ironed, wrapped in covered packages, and sterilized in the steam chamber.

IMPERVIOUS PROTECTIVE MATERIALS

Rubber gloves are now made for surgical uses of material so thin that the motions of the fingers are not interfered with and the sense of touch but slightly blunted. They should come well above the wrists. They should be examined for holes by filling with water. Holes are mended by using a patch from an old glove and rubber cement. This cement if too thick may be thinned with benzin. Large tears in the fingers may be covered with finger cots. Rubber gloves, like all rubber tissue when stored, should be dried and dusted with corn starch or talcum powder both inside and outside, and kept in tightly covered receptacles to exclude air and light. The excess of powder is rinsed off and the gloves boiled for fifteen minutes. Or they may be sterilized by steam at 120°C. (248°F.) under 15 pounds pressure.

The *sulphuric acid method of sterilization* consists in washing the gloves well and then placing them for ten or twelve hours in a 1:200 solution of sulphuric acid. They are then rinsed in salt solution, and are ready for use.

The disinfection of rubber gloves and other rubber articles by the *glycerin method* allows of sterilization by heat without apparent harm to the rubber. The gloves should be put in a wire box to hold them under the glycerin. They should be heated in a receptacle having double walls to provide equable heat. Gloves covered with glycerin and heated for thirty minutes in such an apparatus at 110° to 115°C. (230° to 240°F.) will be found to be sterile. By thoroughly cleansing the article before putting it in the glycerin, the latter may be used repeatedly.

It is said that gloves are damaged by the absorption of water. *Sterilization by dry air*, the gloves being distended with talcum powder to prevent the rubber surfaces from lying together, is effective. After being cleansed, if gloves are dipped in a 20 per cent. suspension of talcum powder in alcohol, and then laid on asbestos, supported by a wire frame, and subjected to dry heat at 75°C. (167°F.) for forty-five minutes they will be found sterile and coated with the powder.

Some surgeons are satisfied with simply washing the gloves with soap and warm water, rinsing in alcohol, and storing until needed in a jar of alcohol containing 1:1000 bichloride of mercury.

Where many gloves are used they may be kept on hand sterilized. For handling sterilized gloves, a number of sterile towels and two pairs of long forceps are required. After boiling, the gloves are carefully lifted out of the water with forceps grasping one or more finger tips. They are laid out flat on a towel and the residual water squeezed out with another towel. When the outside is dried it is dusted with sterilized talcum or starch powder and the glove turned inside out. This is done as follows:—The cuff is grasped in the middle of one edge with forceps, lifted up and the other forceps passed into the glove and made to grasp the inside at a finger septum. The glove is then turned inside out, excepting the fingers. The fingers are turned by grasping both thicknesses of the wrist at the extreme edges, slightly opening the wrist so that some air enters, and then whirling the glove around between the two forceps, until the opening is twisted shut. This may be continued, or a little pressure made upon the ballooned-up portion, and the fingers will be everted with a "pop." The outer side now may be dried, dusted with sterile powder, and the gloves laid away between layers of

sterile cloth. Instead of forceps for this operation the nurse's gloved hand may be used.

In the hospital, sterilized gloves may be kept in a bag, like a shoe bag, having a marked compartment for each size. Gloves are more satisfactory when kept dry and used dry. After using, rubber gloves should be washed in cold water to dissolve the blood, and then washed with soap, rinsed, and carefully dried inside and outside.

Finger cots of rubber are sterilized by boiling. They should be much used to protect weak places in rubber gloves, to cover infected fingers, and to prevent infection of the surgeon in making examinations.

Rubber sheeting should be kept on hand for making bed sheets, rubber protectors, pad covers and aprons. It is cleansed by washing with plenty of soap and water.

The **rubber pad** is an air ring, having a rubber bottom to receive and carry off fluids. It is cleansed by scrubbing with soap and water.

Gutta-percha solutions have been employed by some surgeons. For the purpose of coating the surgeon's hands after disinfection a solution is made of sterilized gutta-percha chips (4 or 8 per cent.) in benzin. The gutta-percha and the cotton through which the solution should be filtered should be sterilized by formalin. The hands should be thoroughly dried before its application. The hands are immersed in the solution, care being taken to cover all of the skin and particularly about the finger nails. They are then permitted to dry with the fingers separated, after which they are washed with alcohol and bichloride solution. During operations this covering tends to wear off at the finger tips, and another application of the solution must be made. Benzin dissolves off the covering when no longer required. A similar solution may be used to cover the skin through which an operation is to be done. A solution for painting over wounds is made by saturating chloroform with gutta-percha.

Gutta-percha differs from rubber in being plastic as well as elastic. When warmed the folds of gutta-percha adhere. A sheet of gutta-percha is very useful for covering dressings which it is desired should be kept dry or impervious. Hot water applied with a sponge causes it to adhere to the skin or to another layer of gutta-percha. Cold, following this, leaves it firm and smooth.

Collodion is a solution of freshly prepared gun cotton in ether and a little alcohol. It is naturally sterile. It is used to paint over slight wounds, and abrasions of the surgeon's hands which might transmit or receive infection, and also to cover aseptic wounds. The ether evaporates and leaves an adherent air-tight film. The surface upon which it is painted must be dry. A good artificial scab is made by painting such wounds with iodoform collodion (1:10).

Rubber dam is made of thin sheets of elastic rubber. It is employed for many purposes in surgery where a strong, elastic, and pliable waterproof covering is desired. It is sterilized by boiling in water. When it is desired to keep it sterilized it is best to dry it and treat it after the manner of treating rubber gloves.

Rubber tissue, for covering skin-grafts, etc., is sterilized by washing with green soap and cold water, rinsing in plain water, immersing for a day in 1:1000 bichloride solution, drying and rolling between the layers of a sterile towel or muslin cloth. Formaldehyd sterilization also may be used. It may be sterilized by heat the same as rubber gloves.

Oiled silk protective is a tissue used for covering skin-grafts and for interposing to prevent adhesions to dressings. It should be cut into strips

5 cm. (2 inches) wide, loosely rolled upon a muslin bandage as a spool, each layer being separated by a layer of gauze bandage, and sterilized by fractional sterilization at 100°C. (212°F.), or given one heating in a closed jar in the steam chamber.

Oiled muslin is a coarser fabric than oiled silk. It is used to cover dressings and poultices in order to prevent evaporation, and as a waterproof adjunct to dressings and splints.

Waxed paper and paraffined paper, for uses similar to oiled muslin, and for wrapping salts, are made by pouring melted wax or paraffin upon smooth sheets of paper of the desired thickness, and ironing with a hot smoothing

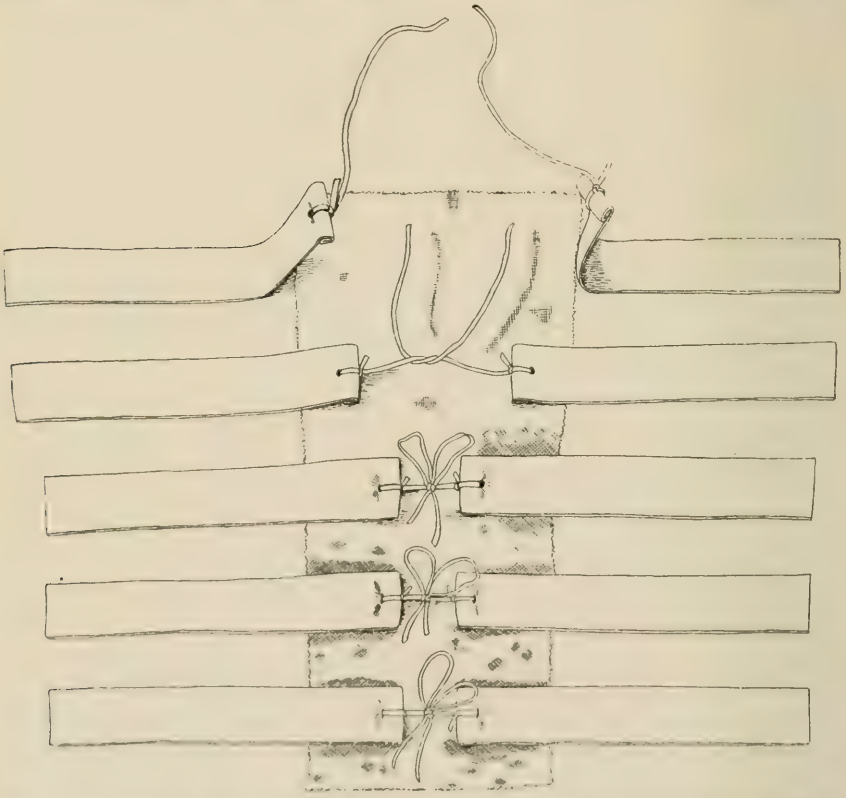


FIG. 25.—ADHESIVE TAPES, USED ESPECIALLY TO RETAIN DRESSINGS WHICH NEED FREQUENT CHANGING.

This same principle may be used in closing wounds or in relieving the tension on wounds.

iron; or the paper may be dipped into the melted wax or paraffin and then passed through a laundry mangle.

Silver foil is sterilized in the steam sterilizer. It is used to cover wounds.

Adhesive plaster consists of muslin over one surface of which has been spread a mixture of litharge, olive oil, resin and soap. It is made less irritating to the skin by adding zinc oxid to the mixture. It must be applied to a dry surface. The adhesive power deteriorates with handling. Hairy skin should be shaved before applying the plaster.

A similar mixture, containing more resin, is spread upon drilling, and is called **resin plaster or mole skin.** These plasters adhere best when slightly

warmed, enough to soften the adhesive material, by dry heat. They are very useful for many purposes, such as supplementing bandages, in holding splints and dressings, in applying extension to fractures, and in immobilizing parts. The zinc oxid plaster may be sterilized and used as a direct application for closing wounds.

If the skin has become wet, adhesive plaster will not adhere. The skin may be dried by wiping it with alcohol, followed by ether, and it will be found that the plaster will then adhere. To remove adhesive plaster, gasoline, oil of wintergreen, lard, lanolin, or 10 per cent. of oil of wintergreen in lanolin, may be used. These substances soften the plaster.

Adhesive tapes are made by tying a tape in the end of an adhesive plaster strap. A series of these straps, on either side of a dressing, permits the tapes to be tied across the dressing, holds it on, and allows its removal and changing by simply untying the tapes (Fig. 25).

Plaster lacing is made by sewing hooks to the ends of adhesive strips. These are applied on either side of a wound, and with a sterile lace, the wound may be closed without sutures (Fig. 110).

Adhesive Paste.—For making an adhesive glue which may be used to cause cloth to adhere to the skin when adhesive plaster can not be obtained, the following formula is useful: Resin, 50 Gm.; alcohol, 50 c.c.; benzine (pure), 25 c.c.; Venice turpentine, 5 c.c. The resin should be powdered, half of the alcohol should be added, then the turpentine and benzine, and finally the remaining alcohol. The paste may be removed with benzine.

Another useful formula is that of M. Sinclair (Brit. Med. Jour., July 14, 1917). It consists of 50 parts glue, 50 parts water, 2 parts glycerin, 2 parts calcium chlorid, and 1 part thymol. This may be heated in a water bath when used and applied to the skin with a brush. By adding to the above, 50 parts isinglass and 12 parts tannic acid, the adhesive is made somewhat more elastic.

BANDAGES

Bandages are made of several different materials. They are used for retaining dressings, for making pressure, and for purposes of immobilization. The materials are torn or cut in strips and rolled into what is called the roller bandage. For this purpose a simple machine is used, or the bandage may be rolled by hand. Bandages to be applied next to the skin should not have a selvage edge or seams. The loose warp threads at the edge should be pulled out.

Muslin bandages are made of unbleached and of bleached muslin. For the former, strong muslin, cut into 7-meter lengths, is torn into widths of 3, 5, 7, 8, and 10 cm. (1⅓, 2, 2½, 3, and 4 inches). The material should not be so firm as to be without some elasticity. Bleached muslin is used for smaller bandages for use about the hands, feet and head. These are made in 4-meter lengths in widths of 1.25, 2, and 2.5 cm. (½, ¾, and 1 inch). A head bandage is made 7 meters long and 4 cm. (1½ inches) wide. The bleached muslin bandages should be wet before applying to prevent slipping. Roller bandages which are too wide may be cut in two with a thin bladed knife, such as is used for cutting bread.

Gauze bandages are made of bleached cheese cloth, 7 meters long and 7 and 9 cm. (3 and 3½ inches) wide.

Flannel and tricot bandages are used for slight elastic compression, or for a thin, smooth and even covering next to the skin. They are made in 6-meter lengths and in widths of 5, 6.5, 7.5, and 10 cm. (2, 2½, 3 and 4 inches).

Tricot and flannel bandages have the advantage of elasticity (see Bandages, Vol. III).

Rubber bandages are made of pure rubber and of rubber elastic webbing. The former is the bandage of Esmarch which is best used in the 9-cm. (3½-inch) width and 15-meter length. The pure rubber bandage is spoiled after being boiled a few times. It is treated best by scrubbing it with soap and water, rinsing in clean water, drying, powdering with talcum or starch powder, rolling, and keeping it in a round tin box which can have its lid sealed on with adhesive plaster to exclude the air. A bandage treated in this manner will last for a long time. Before being used, it should be unrolled, the powder washed off, the bandage immersed unrolled in antiseptic solution, and then before its application rolled up with the tape end inside. If necessary it may be boiled. If not necessary the soaking in antiseptic may be omitted. It is spoiled by contact with oil and its life is greatly shortened by boiling.

Starch bandages are made of *crinoline* impregnated with starch. In much of the crinoline of the shops there is enough starch to keep the bandages faintly stiff. In addition to this, some starch may be rubbed in the meshes as the bandage is wound. Before using they are dropped in warm water and squeezed out. They are employed in 15-meter lengths and in 5, 6, 7.5, and 10-cm. (2, 2½, 3 and 4-inch) widths. Or a dressing may be painted over with starch or book-binder's paste. Strips of paper may be incorporated in the splint. Starch requires one or two days to become dry. It is understood that the starch used in starch bandages has had the starch granules broken by heat and moisture. This is best done before the starch is put in the bandage. Cold water should first be added to make a creamy mixture. This should then be heated and stirred until the starch takes up the water and swells into a pasty mass. In this mass the bandage should be rolled or the paste may be painted on while the bandage is being applied. It is best made fresh, as it will not keep unless sealed to prevent evaporation and asepticised to prevent moulding.

Water-glass bandages are made by dipping roller bandages of starch-free crinoline or other absorbent material into a solution of liquor sodii silicatis, 1 part, and liquor potassii silicatis, 2 parts. A similar result is secured by painting the bandage after it has been applied with this solution. It requires twelve to twenty-four hours to harden. The solution should be freshly made. Care should be taken that the skin is well protected. Plaster-of-Paris, chalk or cement may be mixed with the water-glass. They make it harden more quickly and produce a stronger splint. By dusting the surface with the dry powder and painting it over with alcohol it takes on a smooth glossy finish.

Tripolith is a preparation made of plaster-of-Paris with a little silicate of aluminium and charcoal. It is somewhat lighter than plaster-of-Paris, hardens more quickly and when hard does not absorb water so easily.

Dextrin dressing is applied the same as starch. One hundred parts of dextrin are mixed with 60 parts of spirits of camphor and 50 parts of water. It requires five or six hours to harden.

Cement dressing is prepared by mixing 1 part cement with 2 parts of plaster-of-Paris. It is used like the plaster dressing, and is somewhat cheaper and nearer waterproof.

Glue dressing is made by laying on strips of manilla paper and painting them with a mixture of equal parts of joiner's glue and oxide of zinc, melted in a water bath. A few layers of gauze bandage are added. Pasteboard strips may also be used.

Magnesite dressing for immobilizing purposes is made by mixing finely powdered *magnesite* into the water-glass solution until a thick paste is formed. This is applied by soaking bandages in it or by painting each layer of bandage after it is applied. Magnesite may be used alone. It is made by dissolving 20.44 parts of magnesium chloride in 16 parts of water. The crinoline bandage is soaked in this cream, and applied as a plaster bandage. Dry calcined magnesite is then rubbed on the outside of the bandage till the excess of moisture is taken up. But two layers of such a bandage are required for most purposes.

Gum mixtures are made by dissolving lime or cement with casein, albumin, glue, gum shellac, or gum arabic, and water. Powdered chalk and gum arabic, resin, resin and wax, paraffin and stearin, collodion, and celluloid are all used to make solutions for giving stiffness to dressings. Other splint materials will be described in the chapters on The Treatment of Fractures.

Plaster-of-Paris bandages are made by incorporating the finest dental plaster into the meshes of bandages. Usually these bandages are made of the crinoline as it comes from the shops, but a more satisfactory result is secured if the starch is washed out of the crinoline before making the bandages. Bleached gauze is sometimes used. The material should be cut in strips 7 meters long, and in widths of 5, 6, 7.5, and 10 cm. (2, 2½, 3, and 4 inches). The bandages should have the plaster powder rubbed in the meshes and be loosely rolled, or, as they are being rolled, they may be run through a box containing plaster. Such a machine is made for hospital use. Besides the plaster held in the meshes of the bandage there should also be some between the layers. The bandage should be rolled loosely so that water can easily reach this when the bandage is used.

Plaster-of-Paris absorbs moisture from the air and when thus hydrated does not harden well; for this reason it is well to dry the bandages in the oven before using. After the bandages have been made, they may be wrapped in paraffin paper and kept in tin boxes having the lids sealed with adhesive plaster. The method of using plaster-of-Paris bandages is described under Fractures (page 477; see also Bandaging, Vol. III).

SOLUTIONS, APPLICATIONS AND ANTISEPTICS

Water which has been sterilized by boiling has largely supplanted antiseptic solutions in surgery. Much of the use of antiseptics in water is not so much for its medicinal value in wound treatment as it is for the purpose of sterilizing the water. Boiling, however, is the only process which accomplishes this end satisfactorily. Boiled water, both hot and cold, should always be on hand accessible to the hospital operating room. For this purpose an apparatus (Fig. 10) which filters, sterilizes by boiling, and stores in air-tight receptacles water, both hot and cold, is used. In making up solutions for use in the operating room, sterilized water should be used whether the solutions are antiseptic or not.

Steam is employed as a therapeutic agent as well as for sterilizing. It is conveyed by rubber tubing from a vessel of boiling water or by connecting the tubing with a steam pipe. Steam is conveyed into the uterus by means of a uterine irrigator. When it is carried into the uterus, bone cavities, etc., care must be taken by proper packing to avoid burning healthy tissues. Usually the steam is applied for about two minutes at 100°C. (212°F.) and then for one minute at 115°C. (239°F.). But little pain is caused by it. Its value lies in its sterilizing action and in its power to produce local congestion. A certain amount of necrosis of tissue is necessarily caused.

Oil.—Many oils are used in surgery; olive oil, cottonseed oil, and paraffin oil. *Olive oil* is employed as a lubricant for urethral instruments and as a vehicle for medicaments. It is sterilized by boiling and should be kept on hand in a stoppered bottle. When used the mouth of the bottle should be wiped off with a sterile piece of gauze and the desired amount of oil poured out. Instruments and sponges should not be dipped into the bottle. Oils cause elastic rubber to deteriorate when brought in contact with it.

Vaselin for lubricating purposes may be sterilized by heat in small bottles.

Irish moss lubricant is made of the gelatinous part of Irish moss. It is put up in tubes, and has the advantage of being a good lubricant and soluble.

Glycerin is a mild antiseptic. It is stable, can be heated, mixes with both water and oils, and is an excellent lubricant. It finds many uses in surgery.

Salt solutions, having a specific gravity and reaction similar to serum minus albumin, are used for wound irrigations. Such solution is practically non-irritating to the divided tissues or to mucous membranes, whereas plain water is irritating to the tissues and to mucous membranes which are not accustomed to it. For washing foreign matter and blood out of wounds the best irrigating material is sterile saline solution. It has quite supplanted the antiseptic solutions, which do harm to the living cells of the tissues, diminish vital resistance and leave a layer of necrosed cells covering the wound. The salt solution commonly employed is made by adding 9 grams (138 grains) of sodium chloride to 1 liter (1 quart) of filtered or distilled water. This 0.9 per cent. salt solution has the same freezing point as the blood and, therefore, the same osmotic index.

A saline solution which approaches still nearer the composition of blood-serum and which is employed for saline intravascular infusions is as follows: Sodium chloride 0.90, potassium chloride 0.03, calcium chloride 0.02, water 100.00. These solutions should be sterilized either by boiling or in the steam chamber. The best method of preparing the solutions is to have the salt on hand in sterilized packages of measured quantities. It should be added to the water in narrow-necked flasks containing 1 liter. The flasks should be plugged with clean cotton, the cotton covered with a few layers of gauze, and the whole sterilized in the steam chamber for half an hour on two successive days. When required for use the contents of these flasks may be warmed to the desired temperature by setting them in a vessel of hot water.

A solution of sodium chloride 3 or 4 per cent. and sodium citrate 1 per cent. in water is known as **Wright's solution.** Sodium citrate (1 per cent.) in contact with the tissues causes a precipitate of the calcium salts in the serum. As calcium is essential to coagulation, its removal from lymph and serum in wounds, prevents plastic deposits and coagulation, and a free discharge of serum is produced. The sodium chloride favors osmosis. This combination is used for dressing abscesses and wounds in which this property is desired. It is contraindicated if there is continuous oozing of blood from the wound.

A solution which contains nourishment for the cells is known as **Schiassi's serum.** The formula is 6.5 Gm. sodium chloride, 0.3 Gm. potassium chloride, 1 Gm. fused calcium chloride, 0.5 Gm. sodium bicarbonate, 1.5 Gm. glucose, and 1000 Gm. distilled water. It is used for the physiologic treatment of wounds.

A valuable modification of saline solution is **Ringer's solution,** the formula of which is 0.2 Gm. potassium chloride, 0.2 Gm. sodium bicarbonate, 9 Gm. sodium chloride, and 1 liter distilled water. **Locke's solution** is 9 or

10 Gm. sodium chloride, 0.2 Gm. calcium chloride, 0.1 to 0.2 Gm. potassium chloride, 0.1 to 0.2 Gm. sodium bicarbonate, 1 Gm. glucose, and 1 liter distilled water.

Beef serum is stimulating to wounds and promotes granulation.

Antiseptics

Bichloride of mercury (mercuric chloride, corrosive sublimate, hydrargyrum chloridum corrosivum) is one of the most powerful of chemical disinfectants. It is a white, crystalline, odorless powder, very poisonous, soluble in water (1:16), in alcohol (1:3), and also freely soluble in ether and volatile oils. Light and air hasten its decomposition. In the pure state it decomposes on coming into contact with metals. It also decomposes the metal, making it objectionable for sterilizing instruments. It can not be contained in metallic vessels unless porcelain-coated. Ordinary water contains a large number of foreign ingredients which decompose bichloride. For this reason distilled water is most satisfactory although filtered water may be used. Solutions made with ordinary water soon lose disinfecting power because of decomposition of the bichloride.

Bichloride solutions cause a necrosis of living cells with which they come into contact, leaving a precipitate of mercury, combined with albumin, thereby adding to the necrotic detritus which in the presence of infection serves for pabulum for bacterial growth. Some person's skins are particularly susceptible to the influences of bichloride, and develop a dermatitis which recovers after discontinuance of the irritation. The drug is also absorbed from wet dressings, and in some cases gives mercuric constitutional symptoms—intestinal colic, diarrhea, salivation. Bichloride of mercury has a large number of incompatibles, among which are alkalies, metals, albumin, many acids, vegetable astringents, etc.

A solution of the strength of 1:1000 kills spores of bacteria; 1:2000 and 1:3000 are the strengths commonly employed for cleansing purposes, although dilutions up to 1:10,000 are employed; 1:500 is used for special disinfections. When necessary these strengths may be applied to wounds although now it is rarely used for this purpose. Solutions stronger than 1:2000 are apt to be irritating to the skin. The solutions should have some acid added to prevent decomposition of the mercuric salt.

Commercially tablets are sold containing 7.3 grains of bichloride and a small amount of citric, tartaric, hydrochloric, or salicylic acid. One of these tablets in a pint of water gives a 1:1000 solution. In the hospital it is best to keep a concentrated stock solution of bichloride in alcohol. A 12.5 per cent. solution is used. Four drams of this to the gallon gives a 1:2000 solution. Stock solutions should have added some anilin color to tint the solution for recognition.

Acid bichloride solution (Harrington) is made in the following proportions: Water 30, alcohol (94 per cent.) 60, hydrochloric acid 6, bichloride of mercury enough to make a strength of 1:1250—*i.e.*, 0.8 c.c. to the liter. Or bichloride of mercury 3.2 Gm., hydrochloric acid 240 Gm., distilled water 1200 Gm., alcohol 2560.

Many other preparations and combinations of mercury are of use in surgery. **Calomel** is a valuable dusting powder, particularly for venereal sores. The iodide, oxycyanide, succinimide, sulphate, and ammonio-chloride of mercury are all antiseptic.

Mercurophen (sodium oxymercury-orthonitro-phenolate) is an organic mercuric compound having enormously greater antiseptic power than mercuric chloride. It is from 25 to 100 times stronger than mercuric chloride

TABLE OF APPROXIMATE QUANTITIES OF STOCK SOLUTION AND PURE DRUG NECESSARY TO MAKE SOLUTIONS OF VARIOUS STRENGTHS

5 per cent. stock sol.	10 per cent. stock sol.	12½ per cent. stock sol.	25 per cent. stock sol.	Pure drug	Strength of solution produced
40 c.c. to 1 liter	20 c.c. to 1 liter	16 c.c. to 1 liter	8 c.c. to 1 liter	2 Gm. to 1 liter	= 1:500
20 c.c. to 1 liter	10 c.c. to 1 liter	8 c.c. to 1 liter	4 c.c. to 1 liter	1 Gm. to 1 liter	= 1:1000
10 c.c. to 1 liter	5 c.c. to 1 liter	4 c.c. to 1 liter	2 c.c. to 1 liter	0.5 c.c. to 1 liter	= 1:2000
6.66 c.c. to 1 liter	3.33 c.c. to 1 liter	2.66 c.c. to 1 liter	1.33 c.c. to 1 liter	0.33 c.c. to 1 liter	= 1:3000
5 c.c. to 1 liter	2.50 c.c. to 1 liter	2 c.c. to 1 liter	1 c.c. to 1 liter	0.25 c.c. to 1 liter	= 1:4000
4 c.c. to 1 liter	2 c.c. to 1 liter	1.6 c.c. to 1 liter	0.8 c.c. to 1 liter	0.2 c.c. to 1 liter	= 1:5000
2 c.c. to 1 liter	1 c.c. to 1 liter	0.8 c.c. to 1 liter	0.4 c.c. to 1 liter	0.1 c.c. to 1 liter	= 1:10,000
150 min. to 1 pt.	75 min. to 1 pt.	60 min. to 1 pt.	30 min. to 1 pt.	7⅜10 gr. to 1 pt.	= 1:1000
300 min. to 1 qt.	150 min. to 1 qt.	120 min. to 1 qt.	60 min. to 1 qt.	14⅘10 gr. to 1 qt.	= 1:1000
450 min. to 3 pt.	225 min. to 3 pt.	180 min. to 3 pt.	90 min. to 3 pt.	21⅘10 gr. to 3 pt.	= 1:1000
600 min. to 2 qt.	300 min. to 2 qt.	240 min. to 2 qt.	120 min. to 2 qt.	29⅗10 gr. to 2 qt.	= 1:1000
1200 min. to 1 gal.	600 min. to 1 gal.	480 min. to 1 gal.	240 min. to 1 gal.	58⅘10 gr. to 1 gal.	= 1:1000

To make solutions of greater strength than these multiply the amount of drug by the desired number or divide the amount of fluid by the same. To make weaker solutions multiply the amount of fluid by the desired number or divide the amount of drug by the same.

as a germicide. In strength of 1:200,000 it kills typhoid bacillus in two and a half minutes. It is a brick red powder, freely soluble, and forms an amber-colored solution.

Chinosol is a yellow crystalline powder, freely soluble in water, giving a solution of acid reaction. It does not coagulate albumin. It is non-toxic. It has antiseptic power equal to mercuric chloride and stronger than phenol. It is strongly antiseptic in solutions as weak as 1 part to 5000. As a germicide it is weaker than phenol, and much weaker than mercuric chloride. It may be taken internally in doses of 0.3 Gm. (5 grains) thrice daily. It is used in solutions of 1:1000. For douching mucous membranes 1:5000 is used. As an eye-wash a 1:8000 solution is used at first.

The halogen derivatives of phenol possess remarkable antiseptic properties.

Chlormetacresol is not toxic; its efficiency is not diminished by albumin; it renders the hands sterile in about eight minutes.

Tritetrabromnaphthol, in 1 per cent. solution, kills colon bacillus within eight minutes, while 1 per cent. phenol requires sixty minutes.

Chloramine (chlorazene) para-toluene-sodium-sulphochloramide, an antiseptic studied by H. D. Dakin (British Med. Jour., Jan. 26, 1916), is non-corrosive, does not coagulate or precipitate protein, is practically non-toxic, and is very stable both in solid form and in solution. It is a white crystalline substance, freely soluble in water, in which it makes a faintly alkaline solution. It has about the same germicidal power as an equal weight of sodium hypochlorite, but is so much less irritating that it may be used in a concentration five times as great. In a strength of 1:1500 it destroys staphylococci and streptococci in serum. In eye infections it is used in 0.1 per cent. solution; 0.2 to 0.25 per cent. in the nose and throat; 0.25 per cent. in bladder and urethra; 0.25 to 0.5 per cent. in the vagina; and 1 to 2 per cent. in infected wounds and for general surgical use. In badly infected wounds the strength may for a time be increased to 3 or even 4 per cent. When strong solutions are used the skin should be protected by ointment.

It is not used in combination with other metals or in alcohol. It may be used in normal salt solution. An ointment is made with 1 or 2 per cent. of the drug, and 2 per cent. of agar. A cream is made with 5 per cent. of sodium stearate.

Sodium hypochlorite used alone, is similar to the above in its action, but is more irritating.

Chlorinated lime (hyposulphite of calcium, bleaching powder) is used to produce *sodium hypochlorite*. "Dakin's fluid" is produced by combining with soda.

The best results have been secured with the following approximate mixture (Daufresne's technic):

Chlorinated lime	200 Gm.
Dry sodium carbonate	100 Gm.
Sodium bicarbonate	80 Gm.

To make the solution the chlorinated lime should be placed in a 12-liter jar with 5 liters of ordinary clean water, and left to stand for twelve hours. The sodium carbonate and bicarbonate should be dissolved in 5 liters of cold water in another jar. The 5 liters of soda solution should be poured into the flask containing the lime solution, the 10 liters of fluid shaken vigorously, and then allowed to stand. At the end of thirty minutes the clear fluid should be siphoned off and filtered through paper. This should be kept in a dark container to protect it from light. The solution is then ready for use. Its active agent is sodium hypochlorite. It is practically isotonic with human blood-serum.

To *test* the above solution, 20 c.c. should be placed in a glass, a few centigrams of phenolphthalein powder poured upon its surface, and the fluid shaken with a circular motion to cause it to swirl. The fluid should remain colorless. If there is an excess of alkalinity due to incomplete carbonization of the hypochlorite, a more or less red discoloration will occur. This is due to error in the technic.

The fluid should never be heated. It is best kept in wicker-covered demijohns of black glass. Light alters it rapidly. If haste is necessary in the preparation the chlorinated lime may be triturated with plain water, but never with the soda solution.

For *volumetric analysis* of Dakin's fluid, to 10 c.c. of the solution add 20 c.c. of distilled water, 2 Gm. of potassium iodide and 2 c.c. of acetic or hydrochloric acid. Into this mixture pour a decinormal (2.48 per cent.) solution of sodium hyposulphite (thiosulphate) until it is decolorized. The number of cubic centimeters of the hyposulphite solution employed multiplied by 0.03725 gives the percentage of sodium hypochlorite in the solution or the weight of sodium hypochlorite contained in every 100 c.c. of the solution.

A solution is correct when, under the above conditions, from 12 to 13 c.c. of decinormal hyposulphite solution are required to cause complete decoloration. Thus:

$$13 \times 0.03725 = 0.485 \text{ per cent. of NaOCl.}$$

This test should be made from time to time to be sure of the character of the solution.

The above solution contains nearly 0.5 per cent. of sodium hypochlorite and a small amount of neutral soda. Stronger solution than this is apt to be irritating, and a solution weaker than 0.45 per cent. not efficient. The ingredients above described are essential. The sodium carbonate

must be anhydrous. The chlorinated lime used must contain an adequate amount of active chlorin. Inasmuch as this varies in commercial products, it should be determined by titration before the solution is made.

The older formula of "Dakin's fluid" is:

Dry sodium carbonate	200 Gm.
Chlorinated lime	140 Gm.
Water	10 liters
Mix and filter	
Add boracic acid	40 Gm.

A *simple method for preparing hypochlorite solution* is as follows (Rosengarten's technic):—A chlorinated soda solution, containing 2.8 per cent. of available chlorin, is used. One liter of this is diluted with 5 liters of water. To this is added 25 c.c. of a 5 per cent. solution of sodium bicarbonate. About 20 c.c. of this mixture is removed and shaken gently with a small pinch of phenolphthalein powder for about two minutes. The solution is ready for use if no red color develops. If a red color appears, 10 or 20 c.c. more of the sodium bicarbonate solution should be added and the mixture shaken. The phenolphthalein test should be repeated till no red color shows.

A powder consisting of equal parts of chlorinated lime and boric acid is called **eupad.** Septic wounds packed with gauze impregnated with this powder are healed by the free hydrochloric acid gas which is liberated. A substance called **eusol** is prepared by shaking 25 Gm. of eupad with 1 liter of water, allowing to stand for an hour and filtering through cotton. Eusol represents a 0.5 per cent. solution of hypochlorous acid. A solution of hypochlorite of calcium (1:1000) is effective in sterilizing infected cavities.

Eusol is used the same as the hypochlorite solutions in the treatment of infected wounds. Hypochlorous acid is corrosive to metals and destroys the dye of colored fabrics.

Eusol solution will keep for three weeks in cold weather and not more than one week in hot weather. It should be kept in the dark.

Calcium hypochlorite, 90, and boric acid, 10, constitute a most useful powder for filling infected wounds.

Titration to Determine the Chlorin Content of Chlorinated Lime.—A 25-c.c. buret graduated in 0.1 c.c.; a pipet gaged for 10 c.c.; and a decinormal solution of sodium hyposulphite, are required.

Decinormal solution of sodium hyposulphite (thiosulphate) can be had in the market. It is prepared by dissolving 25 Gm. of pure crystalline sodium hyposulphite in 1 liter of distilled water, and verifying by the decoloration by this solution of an equal volume of decinormal solution of iodin. The iodin solution is made by dissolving 1.27 Gm. iodin and 5 Gm. potassium iodide in 100 c.c. of water.

An average sample of the chlorinated lime should be taken. Of this, 20 Gm. should be mixed as completely as possible with 1 liter of ordinary water. From time to time it should be shaken. After a few hours it should be filtered. Of this fluid, 10 c.c. of the clear fluid should be taken up with the pipet. To this should be added 20 c.c. of a 1 : 10 solution of potassium iodide and 2 c.c. of acetic or hydrochloric acid. Into this mixture should be dropped drop by drop decinormal solution of sodium hyposulphite until decoloration is complete.

Multiply by 1.775 the number of cubic centimeters of the hypochlorite solution required for complete decoloration, and the result is the weight of active chlorin contained in 100 Gm. of the chlorinated lime. This figure is applied to the following table to find the quantities of chlorinated lime, anhydrous sodium carbonate and sodium bicarbonate which are required to make 10 liters of Dakin's solution.

QUANTITIES OF INGREDIENTS FOR TEN LITERS OF CHLORINATED LIME SOLUTION

Titer of chlorinated lime	Chlorinated lime, Gm.	Sodium carbonate, Gm.	Sodium bicarbonate, Gm.
20	230	115	96
21	220	110	92
22	210	105	88
23	200	100	84
24	192	96	80
25	184	92	76
26	177	89	72
27	170	85	70
28	164	82	68
29	159	80	66
30	154	77	64
31	148	74	62
32	144	72	60
33	140	70	59
34	135	68	57
35	132	66	55
36	128	64	53
37	124	62	52

Example.—If it required 14.4 c.c. of the decinormal solution of the sodium thiosulphate for complete decoloration, the titer of the chlorinated lime in active chlorin is:

$$14.4 \times 1.775 = 25.56 \text{ per cent.}$$

The quantities to be employed to prepare 10 liters of the solution will be in this case:

Chlorinated lime..... 177 Gm.
Dry sodium carbonate..... 89 Gm.
Sodium bicarbonate..... 72 Gm.

If crystalline sodium carbonate is being used, then for every 80 Gm. of dry carbonate, there must be substituted 220 Gm. of crystalline sodium carbonate.

Chlorinated saline solution is much used in France. To 200 Gm. of calcium chloride, 80 Gm. of sodium chloride (c.p.) or 120 Gm. of magnesium chloride in 500 c.c. of water at 50°C. (122°F.) are added. This is poured into a receptacle holding 10 liters and filled with water at 50°C. The fluid is then filtered. While still warm 20 to 30 Gm. of lactic or phosphoric acid are added until the neutral reaction is changed to a slightly acid reaction. The receptacle is then stoppered to prevent further escape of hypochlorous acid. When the fluid cools it becomes slightly turbid with precipitate of lactic or acid phosphate of calcium. This is removed by filtering after the solution has become cool. This chlorinated solution is not irritating like Dakin's solution; it can be used in the warm or cold; it is stable, and seems to give as good results as the chlorinated lime or soda solutions.

Halazone (a dichloramin compound) is a powerful disinfectant which is stable in solid form. In the presence of alkaline carbonate, borate or phosphate, it becomes a powerful bactericide. It was first prepared by H. D. Dakin and E. K. Dunham (Brit. Med. Jour., May 20, 1917). It is slightly soluble in water and chloroform, but freely soluble in glacial acetic acid. A solution is made by dissolving 0.15 Gm. of halazone in 100 c.c. of water and 10 c.c. of 10 per cent. sodium hydroxide solution. Fifteen c.c. of a 10 per cent. potassium iodide solution is added, the mixture then acidified with acetic acid, and titrated with tenth-normal sodium thiosulphate volumetric solution.

Hychlorite is a solution of chlorinated soda, each 100 c.c. of which is said to contain 4.05 Gm. of sodium hypochlorite, 3.20 Gm. of sodium chloride,

0.25 Gm. of calcium hydroxide, and 0.92 Gm. of inert salts. It contains more available chlorin than the solution of chlorinated soda of the U.S.P. One volume of hychlorite diluted with 7 volumes of water is isotonic. It may be used pure, or diluted as high as 1:100 for irrigation.

Liquid chlorin is prepared for distribution in glass ampoules. Each ampoule contains an amount of chlorin to mix with sodium salts and 1 liter of water, giving a standard strength of between 45 and 50 per cent. sodium hypochlorite. This simple method of preparation obviates the complicated filtration, titration and analysis.

Hypochlorite of sodium is the active antiseptic salt of the *liquor sodæ chlorinatæ* (Labarraque's solution) of the pharmacopœia.

Hypochlorite of potassium is an antiseptic similar to the sodium salt. It is the active ingredient of *Javel water*.

Labarraque's solution and Javel water have been used as antiseptics since before the Listerian era; and they are just as good to-day as then. By adding 15 c.c. of either of these solutions to 1 liter of water, an antiseptic solution is secured which is quite as effective as the newer chlorine products which the modern zeal for novelties has created.

Dichloramin-T is a more stable compound than chlorinated soda. The preparation is as follows:—

A good quality of chlorinated lime (350 to 400 Gm.) is shaken with 2 liters of water in a shaker for half an hour. The mixtures is then allowed to settle, the supernatant fluid is siphoned off and the cloudy fluid filtered.

Toluene-parasulphonamid, the powdered crude product (75 Gm.), is then added to the whole of the hypochlorite solution. This should be shaken until dissolved. If the mixture is not clear it should be filtered. It is placed in a large separating funnel and acidified by adding acetic acid (100 c.c.). To remove the dichloramin, chloroform (about 100 c.c.) is added, and the mixture shaken. The layer of chloroform is then drawn off, dried over calcium chloride, filtered, and evaporated in the air.

The solid residue is powdered and dried in a vacuum. This is sufficiently pure for surgical purposes without being recrystallized.

Instead of using toluene-parasulphonamid, the sodium toluene-para-sulphochloramin (chlorazine) may be employed.

Another method of preparing dichloramin is as follows: Para-toluene-sulphonamid (50 Gm.) is dissolved in water (500 c.c.); and to this sodium acetate (100 Gm.) and chloroform (100 c.c.) are added. The vessel is immersed in cold water and a stream of chlorin is passed into the fluid until it is saturated with chlorin. The mixture is then allowed to stand a few hours. If the odor of chlorin disappears more chlorin is added. More chloroform may be added if necessary to dissolve the chloramin. The procedure is then continued as in the first method.

Chloraminated oil is prepared as follows:—Eucalyptol (U.S.P.)—not oil of eucalyptus—is used. Eucalyptol (500 c.c.) is mixed with potassium chlorate (15 Gm.) and concentrated hydrochloric acid (50 c.c.). This is allowed to stand for twelve hours, and is then washed with water and sodium carbonate solution. Dry sodium carbonate is then added to the mixture, and the whole allowed to stand for twenty-four hours. Then it is filtered and dried with a little calcium chlorid.

To prepare chloraminated paraffin oil, 500 c.c. of commercial liquid petrolatum are mixed with 15 Gm. of potassium chlorate and 50 c.c. of concentrated hydrochloric acid. The mixture is allowed to stand in the light for twelve hours. It is then placed in a separating funnel and washed successively with water, sodium chlorid solution, and water. The opalescent oil is drawn off,

one or two lumps of calcium chloride and 5 Gm. of charcoal are added, and the oil filtered with suction.

The amount of liquid petrolatum which may be added to the eucalyptol solution of dichloramin depends upon the length of time it is to be kept. If the solution is to be kept for some time, not more than an equal part of liquid petrolatum should be added to a 15 per cent. solution of dichloramin in eucalyptol. When the mixture is to be used immediately as much as 2 parts of liquid petrolatum may be added to 1 part of the 15 per cent. eucalyptol solution. The mixture with chlorinated paraffin is called chlorcosane.

Dichloramin is a non-irritating germicide which gives off nascent chlorin. It is more easily prepared and is more effective than the watery chlorinated solutions. In deep infected cavities 20 per cent. strength is used; and 5 per cent. strength in secondary dressings and burns. In *burns* it is very useful. It may be used in strengths of from 20 to 40 times greater than can be employed with the usual watery hypochlorite solution. The oil holds the chlorin and gives it off more slowly and constantly than does the watery solution. It seems as effective as iodin solutions but does not destroy the tissue cells (for the application of chloraminated oil, see page 247).

Toluenine and many other chlorin preparations are used.

Flavin (acriflavin, trypaflavin) is an antiseptic which possesses the remarkable property of destroying bacteria without destroying tissue cells. In the presence of serum its potency seems to be increased. It is a chlorin compound, prepared synthetically from coal tar. It was discovered originally for Ehrlich by Benda. The chemical name is diamino-methylacridium chlorid (Brit. Med. Jour., Jan. 20, 1917). It is used in the same strengths as the mercuric salts. One to 1000 is highly effective.

Brilliant green is a useful antiseptic in a paste or 1:200 solution.

Phenol (carbolic acid) was the original disinfectant used by Lemaire and Lister. It is a product of distillation of coal-tar, and occurs in pinkish white crystals, soluble in 15 parts of water, 2 parts of olive oil, freely in alcohol, chloroform, ether, and glycerin. Its action is neutralized by alcohol. It is rendered fluid by adding 5 per cent. of water; for which reason it is kept in stock in the operating room in 95 per cent. strength. It is not so powerful a germicide as bichloride of mercury, but possesses the advantage that it permeates oily substances, retains its stability, does not corrode metals, is a deodorizer, and is slightly anesthetic. The phenol of commerce contains cresol and is less soluble in water than pure phenol. In making solutions it is well to shake the phenol with a small amount of water or mix it with glycerin before adding the bulk of water. It mixes much better with hot water. It is used in watery solutions—1 part to 40, 1 to 30, and 1 to 20; 12.5 Gm. to 1 liter (3¼ drams to 1 quart) = 1:80; 25 Gm. to 1 liter (6½ drams to 1 quart) = 1:40; 33 Gm. to 1 liter (8½ drams to 1 quart) = 1:30; 50 Gm. to 1 liter (13 drams to 1 quart) = 1:20. The stronger solution is irritating to the skin and is too strong to be left applied as a dressing. The weaker solutions may be used for wound irrigations. Like bichlorid it combines with albumin to make an insoluble phenol-albuminate. It kills all bacteria except spores, and mixes more freely with wound discharges than bichloride does.

Phenol produces a necrosis, if left applied long to the skin. Gangrene of the fingers results from doing them up in phenol solution. Its volatile character causes solutions and dressings to lose their antiseptic efficacy after a short exposure to the air and light. The easy absorbability of phenol renders its prolonged contact with the tissues dangerous, necessitating care lest a poisonous amount be absorbed from dressings or be retained in irrigated

cavities. Children are especially susceptible to phenol poisoning and women more than men. Poisoning is characterized by general weakness, sweating, salivation, anorexia, nausea, vomiting, headache, dizziness, head noises, heart weakness, irregular breathing, coma and the appearance of phenol in the urine giving a smoky brown or olive green color.

The local application of pure phenol has recently become one of its most common employments. In this form it is a powerful disinfectant amounting to an escharotic. Its use in this way is made possible by the neutralizing power of alcohol. Phenol when applied pure to the skin, wound tissues, or abscess cavities causes a whitening, due to the combination of the drug with albumin. At the same time, the bacteria in the whitened area are killed, the formation of the layer of coagulated albumin prevents absorption, being thus less dangerous in this respect than diluted solutions. As soon as this bleaching is observed alcohol should be applied, which absolutely neutralizes the phenol and prevents poisoning or further action. So absolute is this neutralizing effect that pure phenol may be placed on the tongue or other sensitive and absorbent tissues, and, if followed immediately by the application of alcohol harm is prevented. The local use of alcohol is the natural antidote for phenol poisoning.

Phenolized glycerin is a good disinfectant, and may be made in any strength desired.

Creolin, made by the distillation of coal tar, is a reddish-brown syrupy liquid, having strong antiseptic and deodorizing properties very similar to phenol but much less toxic. In water it makes a milky emulsion. It is used in 1, 2 and 2½ per cent. strengths, and is a decidedly valuable disinfectant. Fresh solutions only should be used.

Lysol is a brown, oily liquid made by combining creolin or *cresol* with potash soap. It is a valuable disinfectant, cleansing agent, and lubricant; and is used in 1 to 2 per cent. solutions.

Tricresol belongs to the phenol-cresol group. It is less poisonous than phenol, and equally strong as a germicide. It is used in 0.5 to 1 per cent. solution in water.

Cresol is similar in action to phenol but less poisonous.

Solveol is a cresol compound, of antiseptic power equal to phenol and much less toxic. It is used in 1 to 2 per cent. solutions.

Creosote is another antiseptic of value. In 1 : 200 strength it destroys pus bacteria. For cleansing and dressing wounds, it is used in 1.5 and 2 per cent. solution.

Silver nitrate is used in the pure form, fused in sticks, as a cauterant. It is fully soluble in water. It has so many incompatibles that solutions should be made with distilled water. It is decomposed by light, and should be kept in dark, glass-stoppered bottles. It is locally antiseptic, astringent, stimulant, cauterant, and escharotic. Like all the strong antiseptics it enters in combination with albumin, forming an insoluble silver albuminate which makes a sterilized covering over the tissues thus acted upon. It is used commonly in 1, 2 and 5 per cent. solutions; 0.3 Gm. to 30 c.c. (5 grains to 1 ounce) = 1 per cent.; 0.6 Gm. to 30 c.c. (10 grains to 1 ounce), 2 per cent.; 1.5 Gm. to 30 c.c. (25 grains to 1 ounce), 5 per cent. Silver nitrate is one of the best and most important germicides, even in solution as weak as 1 : 1000 or 1 : 5000.

There are a large number of preparations of silver in which the silver is combined with albumin; casein, egg yolk, and white of egg being used. They are called *organic silver salts*. The antiseptic power of all of these is much less than that of silver nitrate. Some of them can not be called bactericidal.

Among these preparations are argyrol, argonin, argentose and argenol. Of somewhat greater antiseptic power than these are collargol (colloidol silver) ichthargan (silver ichthyol), and argentamin (a silver phosphate), itrol (silver citrate), protargol (silver albuminate), silvol, and actol (silver lactate).

Credé applied silver in all branches of wound treatment. He covered wounds with silverized gauze, dusted open wounds with itrol, and impregnated silk, catgut and drainage materials with silver. Itrol and actol are used for irrigation in 1:4000 solution. They are practically non-poisonous. In sepsis, collargol is used as an inunction (unguentum credé, 15 per cent. silver) and for intravenous injections. It is also given internally.

For removing *silver stains* from fabrics they are placed for a few minutes in a solution of 1 Gm. bichloride of mercury, 2000 Gm. water, and 25 Gm. sodium chloride, and then rinsed. A strong solution of iodide of potash also removes silver stains.

Permanganate of potash is a mild germicide and deodorant, having a slight astringent action. It is soluble in 18 parts of water, and is decomposed by alcohol. For disinfecting the hands a strong solution is used and allowed to dry on the hands; 30 Gm. (1 ounce) of crystals of the permanganate in 1 liter (1 quart) of hot sterilized water. This can be washed off with 5 per cent. oxalic acid solution, 45 Gm. (1½ ounces) of oxalic acid to 1 liter (1 quart) of water. The oxalic acid is removed by rinsing in lime water or ammonia water, made of stronger ammonia (1 ounce) to cold water 1 liter (1 quart). Solutions of permanganate of potash for irrigating purposes are made with sterilized water in strengths of 1:2000 to 1:100.

Picric acid is a mild disinfectant and astringent, soluble in alcohol, but slightly soluble in water. Its chief use is in the treatment of burns. It is used in 0.5 and 1 per cent. solutions with a little alcohol. A 1 per cent. solution is made by adding 2.5 Gm. (36 grains) to 30 c.c. (1 ounce) of alcohol and then adding this to 250 c.c. (8 ounces) of water. The 1 per cent. alcoholic solution has penetrating power and is a most valuable skin disinfectant.

Benzoic acid is an antiseptic which is of use as a wound dressing in 1 per cent. solution. It is soluble in 2 parts alcohol, 10 parts glycerin, 500 parts cold water, and 30 parts hot water.

Oxalic acid is a mild antiseptic, inhibiting bacterial growth in 1:400 solution. It may be employed in 1 per cent. solution for washing wounds.

Acetic acid, in 5 or 10 per cent. solution is an antiseptic and astringent, used chiefly in the uterus.

Boric acid can not be classed as a strong germicide. It exerts an inhibiting action on the growth of bacteria. As an irrigating material plain sterile water and salt solution have taken its place. When applied to the skin in strong solution, it has the power of penetrating the tissues. Its chief advantage is that it is non-irritating and can be used in the eye or in other places where irritation can not be tolerated. One to 4 per cent. solutions are used. It is used most in a saturated watery solution which is 4 parts to 100, or 20 Gm. to 500 c.c. (5 drams to 1 pint) or 150 Gm. to 4000 c.c. (5 ounces to 1 gallon). It is best made with hot boiled water and crystals of the acid.

Boric acid lint or *gauze* for wound dressing is made by soaking in a hot concentrated solution and allowing to dry.

Borax (sodium borate) is less poisonous than the acid, and can be used freely in saturated solution (1:25).

Salicylic acid has little value as an antiseptic in watery solutions. There are but few bacteria which it inhibits and still fewer which it destroys. It is feebly soluble in water (1:500). One and 0.2 Gm. (20 grains) are rendered soluble in 30 Gm. (1 ounce) of water by adding 1.6 Gm. (25 grains) of

borax or citrate of potash. It is much used in dusting powders in 2 to 5 per cent. strength. Its inhibiting effect is more pronounced upon the saprophytic organisms than upon pyogenic bacteria. A strong solution can be made with alcohol in which it is used in 2 to 5 per cent. strength. This is a decided antiseptic.

Boro-salicylic solution (Thiersch) combines the merits of two feeble antiseptics into a mild antiseptic solution, the chief merit of which is its non-irritating property. The antiseptic action exerted by this solution is so slight that it has but little more value than plain water or saline solution. As a dressing it inhibits the growth of bacteria. Thiersch's formula calls for 3 parts of salicylic acid, 30 parts of boric acid, and 1000 parts of water.

Formaldehyde (formic aldehyde, oxymethylene) is a gas which is soluble in water, making a 35 per cent. solution. This solution is called *formalin;* it is colorless, has a pungent odor, and is the form in which the drug is supplied by chemists. Only the pure formalin should be used. It is a non-corrosive germicide of much power, its chief objection being the irritating pungent gas (formaldehyde) which it emits and which is so irritating and painful to raw surfaces that even in weak solutions it is not suitable for wound treatment. It is a powerful deodorant and is of much value in sloughing wounds where nerves are not exposed. For irrigation and dressings a dilution of formalin in water is used. Formaldehyde is employed in various strengths, usually from 0.25 to 3 per cent. solutions. Pyogenic organisms are destroyed within thirty minutes by a 1 per cent. solution, their growth being inhibited by a 0.01 per cent. (1:10,000) solution. One per cent. formaldehyde solution is made by adding 25 c.c. (6¼ drams) of formalin to 1 liter (1 quart) of water. A 3 per cent. formalin-glycerin solution is made by adding 18 c.c. (4½ drams) of formalin to 250 c.c. (8 ounces) of glycerin. Because of the non-corrosive property of formaldehyde and its strong germicidal power, it is used as a disinfectant for such materials as are damaged by heat or which can not be heated. For disinfecting rooms and large surfaces, it is the best-known agent. For surgical purposes the gas is most valuable for disinfecting rubber catheters and other rubber articles. The materials are enclosed in suitable jars or boxes in the bottom of which are placed tablets of solid trioxymethylene (polymerized formaldehyde, "paraform" or "paraformaldehyde") from which the gas is gradually liberated by the application of heat.

Hydrogen peroxide (perhydrol) is a watery solution of H_2O_2, 30 per cent. by weight or 100 per cent. by volume. In surgery it is used in various strengths—2 to 10 per cent. It should be kept cool and corked as it readily decomposes. Its very mild antiseptic action is due to the liberation of its one molecule of oxygen, leaving water. It is of particular value as a cleansing agent for use in suppurating wounds and cavities. So long as there is pus present the peroxide will be decomposed and the liberated oxygen will bring up the pus in the form of foam. It has the power to clean out small pockets of pus which are not reached by irrigating solutions. A wound in which catgut has been used to tie vessels or as sutures should not be washed with peroxide, because peroxide is apt to destroy catgut.

Liquor alumini acetatis is an astringent antiseptic. It is a good wash for suppurating wounds. It is used in surgery diluted with from 5 to 15 times its weight of water.

Acetotartrate of aluminium is an astringent antiseptic. It is used in 0.5 to 3 per cent. solution in water.

Iodin is a most valuable antiseptic, being even more effective than phenol. The *tincture of iodin* is one of the best germicides, and is particularly useful as a skin disinfectant because of its power to enter the skin fol-

licles. The solution of iodin in a watery iodide of potash solution is of decided antiseptic power. This is made of 3 parts of iodide of potassium dissolved in 48 parts of water, and to this is added 2 parts of iodin. Iodin water, made by adding tincture of iodin to 74 or 100 parts of water, is a valuable agent for cleansing wounds.

The tincture of iodin is one of the most valuable and most popular antiseptics, both for cleansing the skin before operations and for wound treatment. Painted on the dry skin it penetrates the follicles and produces a better sterilization than can be accomplished with scrubbing and mercuric applications. While 10 per cent. alcoholic solution is commonly used, experience has shown that 5 per cent. solution gives satisfactory results.

Dirty wounds may be sterilized by injecting the tincture of iodin so that the entire wound surface is covered.

It is capable of checking the spread of *erysipelas* when the inflamed area and a zone of the surrounding skin are painted with it. It stimulates sluggish ulcers. For irrigating larger cavities, 4 c.c. (1 dram) of the tincture of iodin in 1000 c.c. (1 quart) of water is an antiseptic of great value. The pure tincture is used for swabbing out the interior of the uterus. For disinfecting the hands a 1 per cent. solution of iodin and potassium iodide is useful.

An *iodin powder* which is highly effective and less disagreeable than iodoform is made by dissolving 5 parts of iodin in 100 parts of ether, and then adding 100 parts of powdered red cinchona. The mass is triturated until the ether is evaporated. It is then rubbed through a fine sieve. A powder containing 10 per cent. of iodin may be made for direct introduction into gangrenous wounds. Stains of iodin may be removed with ammonia water.

Trichloriodin is one of the most powerful iodin antiseptics, nearly as strong as bichloride of mercury, and almost free from danger. In solutions of 1:1000 or 1:500 it disinfects instruments, dressings, and the skin.

Iodoform (CHI_3, teriodide of formyl) is the most used in surgery of the iodin group of powders. It is a crystalline, yellow powder, containing 96 per cent. of iodin. It is almost insoluble in water, acids and alkalies; but soluble in ether (1:7), chloroform (1:20), alcohol (1:60), oils (1:30), in olive oil and glycerin (1:100). It is a mild antiseptic, but has a strong power to *inhibit the growth of bacteria in wounds*. Its chief value is as a dressing for open wounds which are exposed to infection, as after excision of the upper jaw. It is also most useful in injuries and operations affecting the mouth, nose, throat, vagina and rectum, and in local syphilitic and tuberculous disease. Observations up to the present time seem to show that this action is due largely to the peculiar irritating property of the drug which encourages a local outpouring of leukocytes. It provokes local phagocytic exudation; the iodin acting also like an opsonin, to depress the vitality of the bacteria. It is used in gauze for wound packing (see Iodoform Gauze), also in suspension (10 per cent.) in olive oil or glycerin, in powder, and in solution.

Certain bacteria, *streptococci* and *staphylococci*, if introduced into iodoform, remain alive for a long time. For the sake of safety, iodoform may be sterilized by exposing it to formaldehyde. When mixed with glycerin, glycerin naturally being antiseptic, its sterilization may be dispensed with.

To make *iodoform-glycerin*, boil a bottle containing 9 parts of glycerin; and, after it is cooled, add 1 part of iodoform, stop bottle and shake. *Iodoform-ether* is a saturated solution of iodoform in sulphuric ether. *Iodoform-collodion* is a mixture of 1 part iodoform in 10 parts collodion. *Iodoform emulsion* is made by adding 5 or 10 per cent. iodoform to sterilized olive oil.

Iodoform-balsam (Mencière's mixture) is composed of 10 Gm. each of iodoform, guaiacol, eucalyptol, and Peruvian balsam, 100 c.c. of alcohol, and ether to make 1000 c.c. This is sprayed into the wound. The permanent mixture used to fill the wound consists of iodoform, 10 Gm.; guaiacol, 10 Gm.; eucalyptol, 10 Gm.; Peruvian balsam, 30 Gm.; and ether, 100 Gm.

The toxic property of iodoform is one of its chief objections. The maximum internal dose of the drug is 0.2 Gm. (3 grains); and more than this amount may be easily absorbed from wounds treated with iodoform. It must be used with care, and in small quantities, especially in the old, in feeble and anemic individuals, in children, and in persons with diseased excretory organs. The crystalline form is less dangerous than the finely powdered drug. The symptoms of iodoform poisoning may come on a few hours after its introduction or they may be deferred for many days. They affect chiefly the heart and brain. The milder cases of poisoning are characterized by cardiac weakness, by nervous disturbances referable to the gastrointestinal tract, and by headache and mental distress. There is often elevation of temperature. These symptoms may be much more pronounced, running into delirium and coma. A general paralysis of the nervous system may supervene, and death follow. An urticarial or papular eruption is sometimes present. Most cases of iodoform poison are observed in old people. This is partly due to their imperfect power of elimination, as evidenced by the fact that when phenol is employed in connection with iodoform the symptoms of poisoning are much more apt to occur, the excretory power of the kidneys being damaged by the phenol irritation. Granulating surfaces absorb the drug more readily than fresh wounds.

Iodin is set free at the place of application in the tissues. This combines with an alkali and with albumin and in these forms is absorbed by the blood. The albuminate is transformed into organic compounds, containing iodin, which together with the alkaline iodin, are excreted by the urine. Testing urine for the iodin reaction must be done by evaporating and testing the ash, as the organic compounds in solution do not respond to the usual iodin tests.

The *treatment* of iodoform poisoning consists in the immediate removal of all of the iodoform accessible in the wound, and giving attention to the objective indications. The local and constitutional use of alkalies, such as carbonate of potash, facilitates solution and elimination of the drug.

Another objection to iodoform is its penetrating odor. This may be concealed by the addition of powdered tonka bean, tincture of musk, powdered coffee, oil of bergamot, oil of peppermint, or oil of cloves.

Substitutes for iodoform, without its toxicity or evil odor, have developed in large numbers. They are recommended by the virtues of the iodin which they contain. All of these substitutes fail in surgical efficiency when compared with iodoform. Many of them, however, have decided merit. Among them are *aristol*, containing 45.8 per cent. iodin; *iodol*, containing 89 per cent. iodin; *airol*, formed from bismuth subgallate; *nosophen*, containing 60 per cent. iodin, and capable of exposure to a heat of 225°C. (437°F.) without injury; *europhen*, with 28.1 per cent. iodin; *iodoformogen* (albuminate of iodoform); *iodoformin*, a compound of 75 per cent. iodoform and a formaldehyde. Others are *iodoformol*, *iodomuth*, *iodosyl*, and *iodozen*. For a non-iodized powder, subgallate of bismuth may be applied to nearly all of the uses in which iodoform is employed.

Pyxol is used in alcoholic solution with acetone. *McDonald's solution* is composed of pyxol, 2 parts; acetone, 40 parts; and alcohol, 60 parts. It is used the same as iodin, and is much less irritating. It seems to be more

effective than tincture of iodin. Instruments may be left in this solution for long periods without apparent harm. It seems not to irritate serous surfaces; it evaporates rapidly, and does not stain the skin.

Hydrochlorid of quinin is a useful antiseptic in the treatment of infected wounds. A 0.1 per cent. solution should be combined with 0.1 per cent. of hydrochloric acid or 1 per cent. of alcohol.

Balsam-of-Peru is a mild antiseptic which may be employed undiluted to pour into infected wounds. Gauze soaked with it is a useful packing material. It stimulates granulations and is valuable in sloughing wounds. *Balsam of-Peru* (1 part) and *castor oil* (5 parts) make an admirable stimulating dressing for sluggish wounds. *Naphthalin* and *balsam-of-Peru* (1 to 8) is another excellent stimulating application.

Naphthalin, in crystals or powder, is used pure in sloughing, sluggish wounds. It is most effective when combined with balsam-of-Peru.

Beta-naphthol has properties and uses similar to naphthalin.

Pyoktanin is a violet crystalline powder, the solutions of which are very diffusible in animal tissues, penetrating animal cells which have lost their vitality, and thus reaching microörganisms which are included in such cells. It also exerts the same property in the presence of certain tumors. It is an antiseptic of considerable power. It is used pure, and in 1 : 100 solution or even weaker. The stain may be removed by soap, rubbing well and washing with alcohol.

Methyl violet has been used the same as pyoktanin, but its antiseptic power is less. Stains of anilin colors may be removed with hydrochloric acid.

Zinc oxide is a mild non-irritating antiseptic which is used as a powder chiefly to prevent irritation of the skin. *Zinc oxide paste*, made simply with water, is of use in sealing clean wounds.

Zinc stearate is employed the same as zinc oxide. It adheres to the surface better than the oxide but can not be made into a paste so well. It is a valuable vehicle for carrying other more potent powders for covering granulating surfaces.

Zinc chloride is employed as an antiseptic (1 : 500), and as a caustic in 10 per cent. solution with distilled water. It is neutralized by bicarbonate of soda in saturated solution. It has bactericidal action in the strength of 1 : 50.

Zinc sulphate is a freely soluble, astringent, antiseptic. In strong solution it is escharotic. It is used in 0.5 to 2 per cent. solution and in 5 to 10 per cent. ointment.

Zinc sulphocarbolate is a freely soluble, astringent, antiseptic, used in 2 to 10 per cent. solutions. It is non-poisonous and a valuable agent in wound treatment.

Bismuth oxyiodide (bismuth subiodide) is a brownish-red, insoluble, powder, of mild antiseptic and astringent powder. It is of value used pure or combined with other powders, such as zinc stearate, in the treatment of open wounds, ulcers and superficial infections. The bismuth salts are not altogether without poisonous properties and must be used with some moderation.

Bismuth subgallate (dermatol) is a yellow insoluble powder, having about the same antiseptic power as the oxyiodide but more astringent. It is of value pure or mixed with a stearate powder as a dressing to hasten the growth of epithelium over superficial healthy granulation tissue. It is an effective substitute for iodoform. Gauze impregnated with it may be used for packing cavities with about as good effect as is secured from iodoform. It is non-toxic.

Bismuth subnitrate is a mild antiseptic, astringent, insoluble, white, powder of slightly less power than the oxyiodide and subgallate. In rare instances it has caused poisoning when taken in large doses or injected in sinuses.

Bismuth subcarbonate has the same properties as the subnitrate, except that it is free from toxic properties.

Moynihan's cream (a mixture of bismuth subcarbonate and enough 1:1000 watery solution of mercuric iodide to make a paste) is used as a wound dressing. It is a very useful preparation.

Bismuth formic-iodide is a bismuth-iodin-formaldehyde powder. It is used pure as a stimulating antiseptic dressing to superficial wounds, ulcers, and infections.

Bismuth salicylate is a mild antiseptic non-irritating powder.

Bismuth phosphate is a freely soluble bismuth salt, having antiseptic and astringent properties.

Thymol is a non-poisonous, antiseptic product, isolated from oil of thyme. It is soluble in 1 part alcohol, ether or chloroform, and in 1500 parts of water. It is used in solution, composed of 1 part thymol, 10 parts alcohol, 20 parts glycerin, and 1000 parts water. In dilutions of 1 : 10000 it inhibits the growth of pus cocci.

Alcohol (C_2H_6O ethyl hydrate), is much used in surgery in strength varying from 50 per cent. to 95 and 98 per cent. and absolute alcohol; commercial alcohol is about 91 per cent. It is mildly antiseptic, but its greatest germicidal power is exerted when diluted with equal parts of water. In this 50 per cent. strength it is a valuable wound dressing, and is much employed as an injection to hasten the contraction and closure of fistulas.

Alcoholic soap (solidified alcohol) is prepared by adding 150 Gm. of dry and finely scraped castile soap to 500 c.c. of alcohol and 12 Gm. of shellac, and shaking well. The mixture should be heated in a water bath and poured into moulds to harden. This substance lights when touched with a match, and for cleansing purposes seems to possess the advantages of both alcohol and soap.

Terebene ($C_{20}H_{16}$) is an aromatic, oily fluid, having decided antiseptic properties. It is freely soluble in oils, moderately soluble in alcohol, and slightly soluble in water. In the pure form it is valuable for cleansing foul wounds. It is used diluted with equal parts of olive oil for dressing open wounds and ulcers.

Oil of eucalyptus (eucalyptol) is a valuable non-poisonous antiseptic of pungent odor, which is used in 10 to 20 per cent. solution with olive oil as a wound dressing.

Alumnol (aluminium naphthol disulphonate) is a freely soluble, white powder of strong antiseptic and astringent properties. It is used for cleansing wounds in 0.5 to 5 per cent. solutions. In 10 to 30 per cent. solutions it constitutes a caustic. A valuable dusting powder is made by combining it with an inert agent.

Sulphuric acid in 1 : 200 solution is a strong bactericide. As an antiseptic it may be employed in dilutions up to 1 : 1800.

Hydrochloric acid possesses bactericidal power similar to sulphuric acid.

Citric acid is a mild antiseptic, killing pus organisms in 1 : 8 strength.

Iron chloride, in alcoholic solution, in tincture of the chloride of iron, is bactericidal in the strength of 1 part of the tincture to 25 parts water. It is strongly astringent.

Iron sulphate in saturated solution (1:2) is practically non-bactericidal, but in 1:200 solution it inhibits bacterial growth. It is a strong astringent.

Chloral hydrate in 20 per cent. solution destroys pyogenic bacteria. In weaker solutions it is an inhibitive agent.

Ichthyol is a brown syrupy liquid, containing easily liberated sulphur. It is deodorized by adding 0.5 per cent. each of oil of bergamot and oil of eucalyptus. It has mild antiseptic properties and is used locally as an ointment in 5 to 50 per cent. strength.

Ichthyol-glycerin (10 per cent. in glycerin) is used as a hygroscopic antiseptic.

Ichthoform is ichthyol-formaldehyde.

Benzoin varnish (Woelfler's solution), used to paint over raw tissues to prevent absorption and as a peritoneal varnish to seal lines of suture, is made by shaking together 1 part of iodoform and 10 parts compound tincture of benzoin.

Other antiseptics are acetanilid; alum; chloroform; arsenious acid; camphor; charcoal; chromic acid; formic acid; lead acetate, carbonate and chloride; naphthol; potassium bichromate; quinin; resorcin; sugar; sulphates of alkalies; sulphur; ether; tar; tannic acid; and turpentine.

Conclusions.—Antiseptic substances are either protein precipitants or specific antiferments. Protein precipitants act antiseptically by removing the ferment by precipitation, by combining with the substrate, or by their direct antiferment power. Amino-acids and the antiseptics are set free by the ferment action.

The value of these substances is in their power to inhibit the processes of fermentation. The more diffusible and penetrating they are, the more effective. Bichloride of mercury is a strong coagulant of proteid substances. Such chemicals coagulate the proteid of the bacterial cell, as well as of the body tissues. Chinosol is one of the most diffusible of antiseptics. Sodium hypochlorite (the active substance in Dakin's solution) is negative in its chemiotactic action, it scarcely coagulates proteid, and owes its efficiency to its antiferment property. Quinin is not a protein precipitant. Thymol is strongly chemiotactic. Phenol is negative in chemiotactic action. The most valuable antiseptics for wound disinfection are those which do not destroy white blood cells or which have but a slight action on them. Chinosol is one of these; camphor is another. The antiseptics which do not precipitate protein are most effective. They check fermentation in weak solutions.

Caustics

Many of the antiseptics and germicides, when used in more concentrated strength, are caustics and are employed for the destruction of tissue and disinfection at the same time. Many of the acids mentioned above as antiseptics have this power. Among the acids of most value for this purpose are *arsenious, sulphuric, nitric, hydrochloric, acetic, lactic,* and *chromic acids. Bichloride of mercury, zinc chloride,* and *antimony* are also caustics.

Potassium hydrate is made up in the form of sticks which may be held in a holder or wrapped in gauze for safe handling. The surrounding parts should be protected against the caustic's tendency to run.

Silver nitrate is moulded in sticks which may be handled in a holder or forceps. A stick of lesser strength is made by mixing one-third silver nitrate with two-thirds of salt peter.

Copper sulphate has a milder action than either of the above caustics, and is employed in the same manner.

Acid mercuric nitrate is employed in 60 per cent. solution or pure. It can be used to advantage in wounds and ulcers. It is left on for five to twenty minutes and then neutralized with bicarbonate of soda.

Arsenic paste is prepared by making a dough of 1 part arsenious acid and 15 parts starch and water. This causes the formation of an eschar after a few days. It is now but little used as its action is painful.

Vienna paste is made by combining 5 parts of potassium hydrate with 6 parts of quick lime, and just before using, adding enough alcohol to make a thick paste. A layer 5 mm. thick is spread on where desired. This causes destruction of the tissues to which it is applied in from three to fifteen minutes, the depth of the action varying with the length of time it is left. When removed vinegar or a mild acid should be applied to stop the cauterization.

Nitric acid may be used pure in the fluid state and neutralized with an alkali; or it may be employed in the form of *Rivallié's caustic*, which is made by dropping nitric acid upon cotton wool in an earthen vessel. This forms a gelatinous mass, which, when applied to the tissues, causes after half an hour the formation of a yellow eschar. This separates after a day or two, and if necessary the process may be repeated. Bleeding is not apt to occur with this method, and even when applied to sensitive parts of the skin there is but slight pain.

Zinc chloride paste is made by mixing 1 part chloride of zinc; 2, 3, or 4 parts of flour (varying with the degree of cauterization desired); and enough water to make a stiff dough. This will not act through the skin. Like arsenic paste its action is painful.

Measured quantities of many of the above antiseptics and materials may be kept on hand for convenience and economy of time. Powders which are used in certain quantities to make up solutions should be kept in the operating room ready weighed and wrapped in individual powder papers. This is done with such as saline powders for making salt solutions, powders for Thiersch solution, sulphate of magnesia for use in intestinal cases, bichromate of potash, permanganate of potash, etc. Powders and stock solutions should be marked plainly with their names and the amount in each package, also the amounts to be used to make solutions of certain designated strengths, and the fluids in which they are to be dissolved. Salt for salt solution should be sterilized. The *labels* on such packages should never be permitted to become illegible.

Besides the above-mentioned materials for the operating room there should be anesthetics (general and local), stimulants and emergency drugs such as nitroglycerin and adrenalin, benzin for cleansing and for the thermocautery, soap, finger nail scissors, files and cleaners, thermometers, pillows, supports, and chairs.

Filling Materials

For bone chips, bone filling, and bone-wax, see Operations on Bones and Joints.

For paraffin, for injections, see Cosmetic Surgery, Paraffin Prosthetics, Vol. III.

Animal membranes for covering wounds and abraded surfaces and for preventing adhesions are made of thin layers of animal tissue, flattened out, dried, and sterilized. *Cargile membrane* is made from the peritoneum of the cow. "*Cutin*" is made from the peritoneal coat of the intestine of the ox. The strong albuminous lining of the egg shell is also employed. These materials are either secured aseptically, or are spread out and sterilized by formaldehyd gas. Fresh living tissues are better.

SURGICAL INSTRUMENTS

For the ordinary operations of surgery and for surgical treatment certain instruments and appliances are necessary. These should be as simple as possible. They are for the purposes of (1) division of the tissues, (2) treatment of the tissues and (3) uniting of the tissues. Most metal instruments are nickel-plated. Instruments composed of more than one piece should, if practicable, be made so that they may be taken apart for cleansing purposes.

Knives should be made of the best forged steel, preferably of one piece. As sterilizing by boiling is reduced to the minimum of time in order to preserve

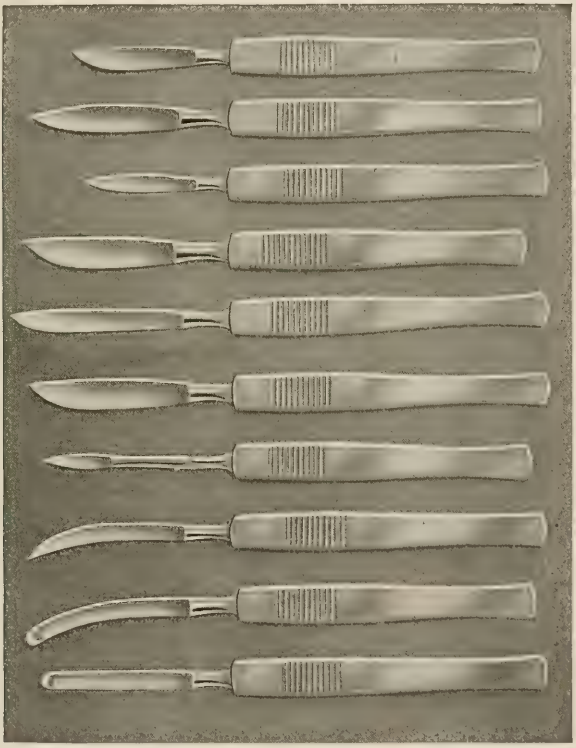


FIG. 26.—KNIVES USED IN ORDINARY OPERATIONS.

the edge, knives should be free from cracks and crevices in which spore-holding dirt might become lodged. The scalpel should be made with a flat spatula-like end to the handle which may be used for purposes of blunt dissection. Knives are also made with blunt points and with curves for opening abscesses (Fig. 26).

Scissors are shown in Fig. 27.

Dissecting forceps for grasping are made with a simple serrated bite and with teeth—**mouse-tooth forceps** (Fig. 28). A combination of scissors and mouse-toothed forceps is made.

Probes and directors are employed for discovering openings, and acting as guides for cutting instruments. Flexible probes are made of silver. Probe-directors are made with a groove on one side to guide a knife (Fig. 29).

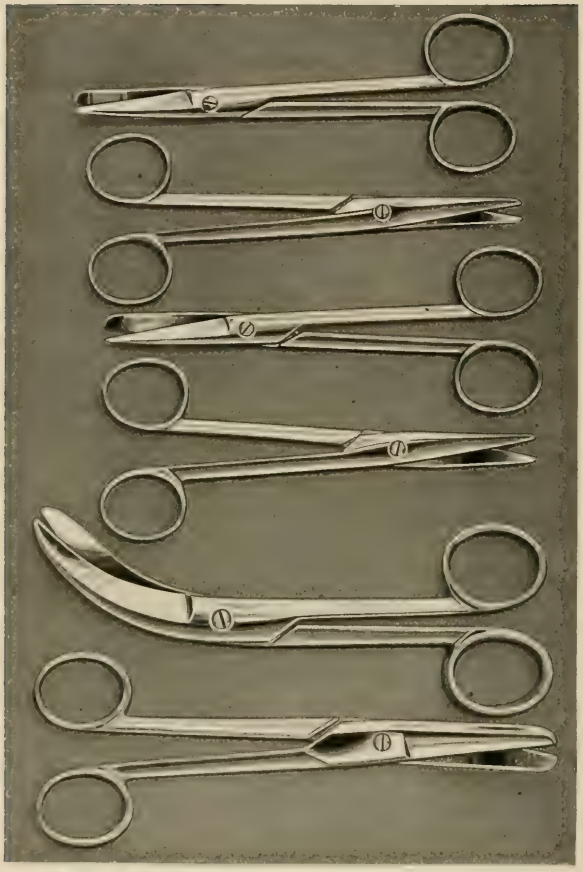


FIG. 27.—SCISSORS USED IN ORDINARY OPERATIONS.

FIG. 28.—FORCEPS FOR GRASPING TISSUE IN ORDINARY OPERATIONS.

Hemostatic forceps (Fig. 30) are made in two types—the round-pointed, over which a ligature in the process of being tied will easily slip; and the toothed forceps, which have the advantage of holding more securely to the tissues. These forceps are not only used for grasping blood-vessels but are employed for many other holding purposes. For this reason they are also

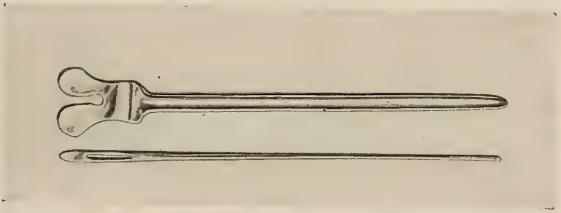


FIG. 29.—GROOVED DIRECTOR AND FLEXIBLE PROBE.

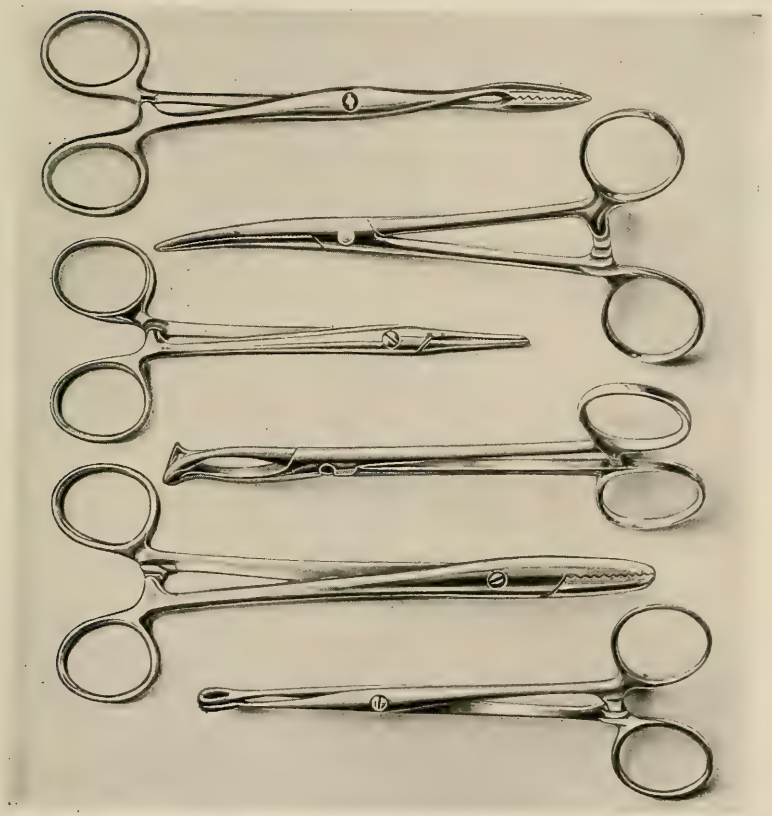


FIG. 30.—HEMOSTATIC FORCEPS.
Various forms of forceps used for grasping blood-vessels in ordinary operations.

made with broad ends as T-forceps, ring forceps, etc. These same forms are also made in long forceps for grasping in cavities or deep recesses.

Retractors (Fig. 31) are used for holding the tissues apart in order to expose deeper parts or for the purpose of making pressure. Self-retaining retractors (Fig. 32) do not require a hand to hold them.

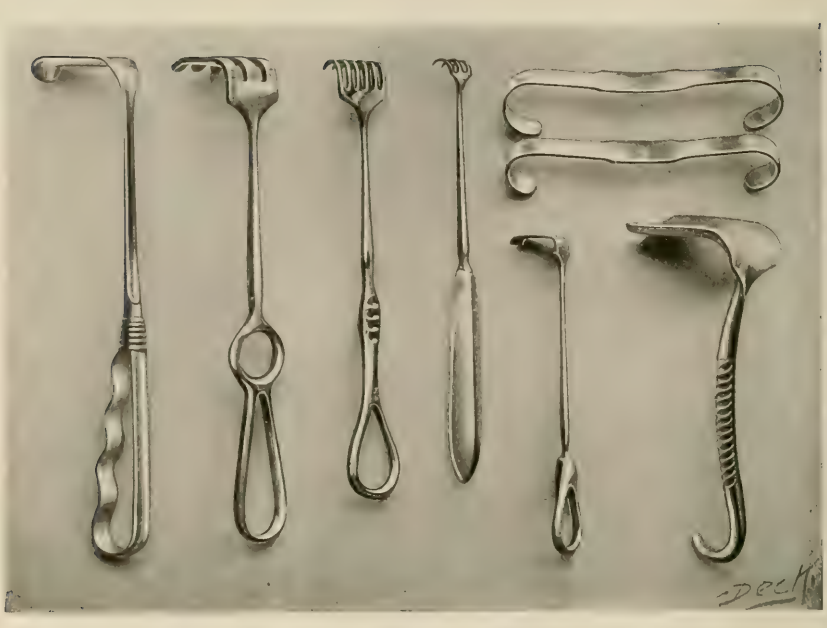


FIG. 31.—RETRACTORS.

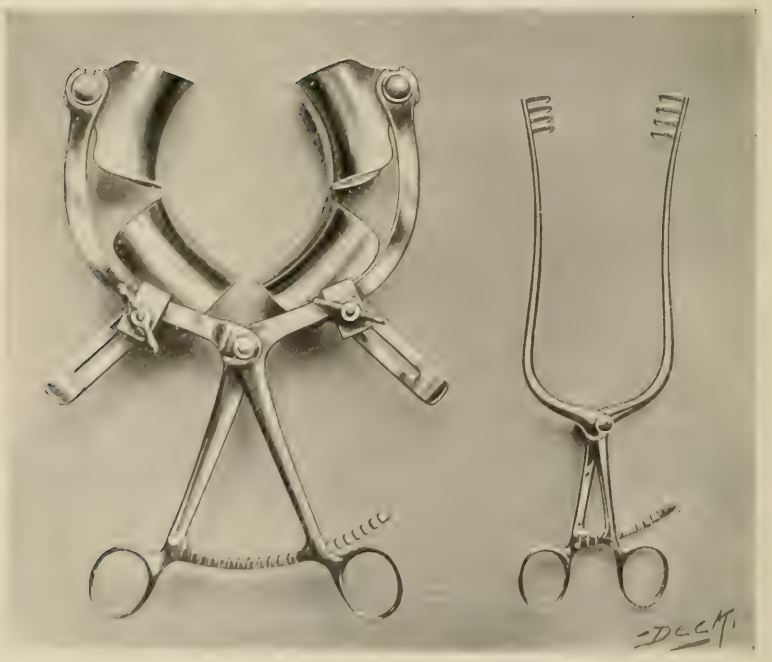


FIG. 32.—SELF-RETAINING RETRACTORS.

Sponge holders, for using the "stick sponge" for sponging in deep places are best made like long ring forceps (Fig. 30). A special sponge holder is made but it is not so useful as the forceps.

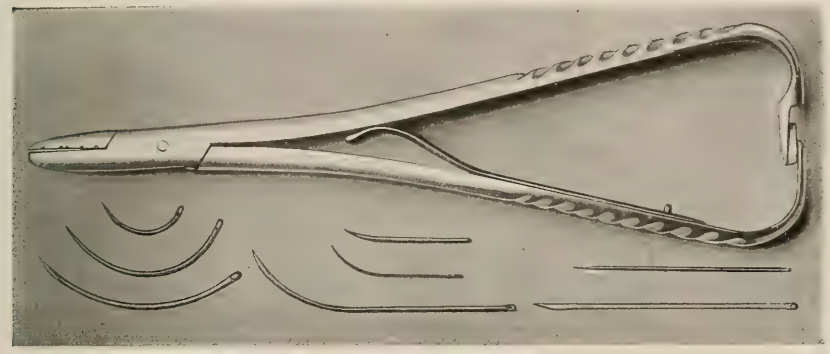


FIG. 33.—NEEDLE-HOLDER AND NEEDLES.

Needles (Fig. 33) are of several styles, special needles being employed for special purposes (Figs. 34, 35 and 35*a*).

Needle holders (Fig. 33) may be of the type of simple forceps, or more complex and specialized. The simpler, the better.

Syringes are for two uses, injecting (Fig. 36) and aspirating. Injecting syringes should be sterilizable, and for this reason some are made of glass with asbestos packing. Others are made with solid pistons, of glass or metal, which exactly fit the barrel and require no packing.

The aspirator is a syringe, usually made larger than the ordinary syringe for injection purposes (Fig. 37). It may be used with only its needle, or, for convenience of manipulation, the needle may be connected to the barrel by a thick-walled rubber tube. When large amounts of fluid are to be aspirated a bottle from which the air can be exhausted is introduced between the needle and the syringe (Fig. 38).

The trocar and canula (Fig. 39) are employed for emptying cavities without using suction. This instrument consists of a tube encasing a sharp-pointed staff, which is used to pierce (Fig. 40) the wall of a cavity containing the fluid; the trocar being withdrawn leaves the canula for the escape of the fluid.

FIG. 34.—SPRING-EYED NEEDLE. Showing eye. This needle may be attached anywhere along the continuity of the thread without passing the end of the thread through the eye.

The snare and ecraseur are used sometimes for dividing tissues by crushing. They are employed chiefly for the division of pedicles.

FIG. 35.—WEDGE-EYED NEEDLE OF MCRAE. IN WHICH THE THREAD ENGAGES IN THE APEX OF THE EYE AND CAN NOT SLIP OUT.

The angiotribe is another crushing instrument used also for this purpose (see Blood-vessels). This instrument by its crushing action closes the mouths of the blood-vessels.

The actual cautery in its simple form, is secured by heating the end of a metal bar or staff in a flame or bed of coals. It is the historic form of surgical cautery.

FIG. 35*a*.—DOUBLE POINTED NEEDLES.

The electrocautery is also applied to the same end. When used as a snare it consists of a wire through which a strong electric current is passed, heating it to a sufficient degree to burn through the tissues. A similar principle is applied to an electrohemostatic clamp which crushes the tissues and at the same time carbonizes them by electric heat (see Blood-vessels).

The cutting cautery is employed in deep and inaccessible cavities such as the nose and throat. This consists of blades of different shapes, fitted

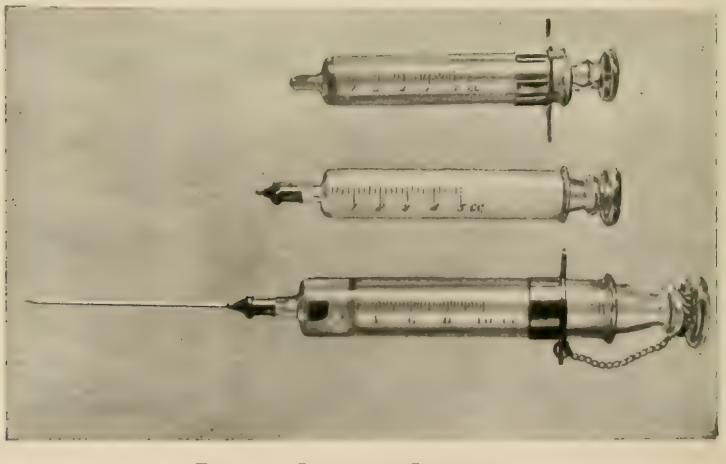


FIG. 36.—INJECTING SYRINGES.

Both barrel and piston of these syringes are of glass. The tip is ground to receive the needle They are used especially for local anesthesia and other medicinal injections. (*Allen.*)

to the end of a handle, which can be made red or white hot by the electric current, the other parts being protected. The electricity for these is furnished by a battery, by a current from the rotary induction machine or by the ordinary light and power current (Fig. 41).

The thermocautery (Fig. 42) heated by benzin or gasoline vapor, may be used for the same purposes as the electric cautery. This is the cautery of Paquelin. The tip is held in a flame until it is red hot. The benzin vapor is then pumped in by squeezing a bulb. It is used at a dull red heat. The

surgeon takes hold of the handle with a sterile towel. It should not be brought too near the anesthetic. After using, the tip should be thoroughly heated and then left to cool slowly.

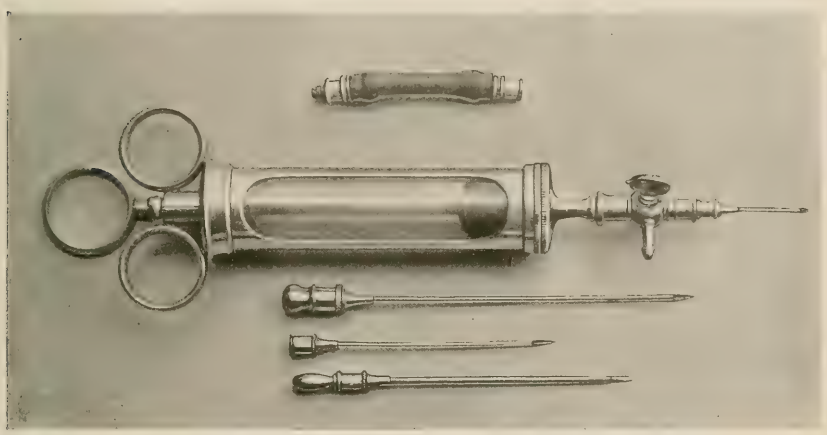


FIG. 37.—ASPIRATING SYRINGE WHICH MAY BE USED ALSO AS AN INJECTING SYRINGE.

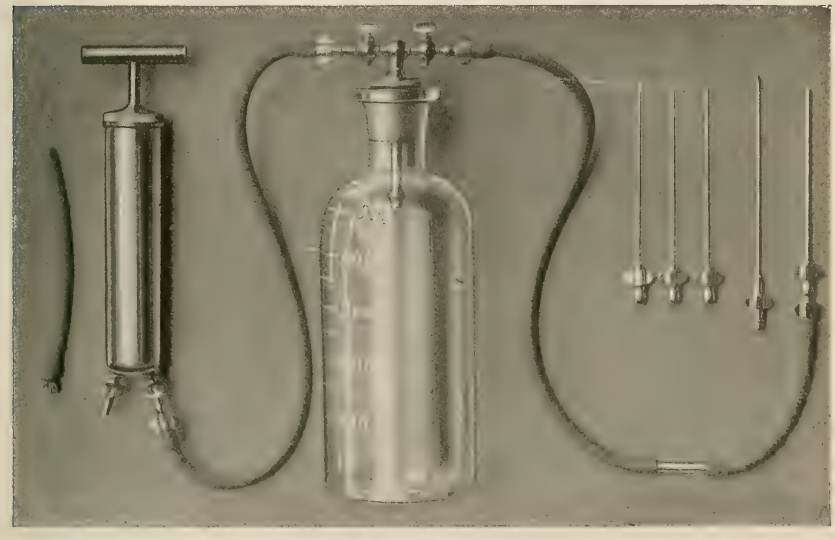


FIG. 38.—ASPIRATING JAR.

The suction syringe serves as a pump to remove the air from the jar. After the needle has been inserted the cock which closes the inflow tube is opened and the negative pressure in the jar brought into action. This apparatus is used especially to remove the fluid from cavities such as the pleura, joints, cystic tumors and the bladder.

Dishes and vessels (Fig. 43), of different shapes and sizes are employed for containing solutions and materials. These should generally be made of glass or metal coated with porcelain and should be free from cracks and crevices. Bottles containing solutions should be corked with ground-glass stoppers or closed with plugs of cotton.

Irrigation receptacles (Fig. 44) should be made of the same material and may be provided with stands.

Brushes for skin cleansing are best made with wooden backs. They should not be so stiff as to abrade the skin. They are sterilized by boiling ten or fifteen minutes in a 10 per cent. solution of potassium bichromate, from

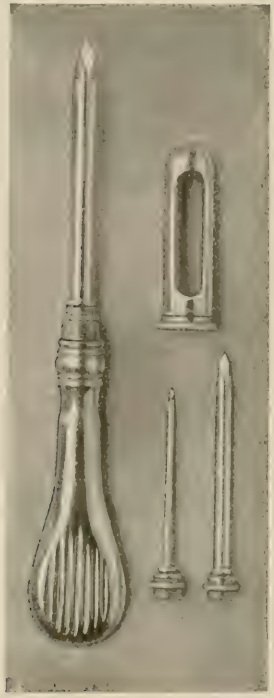


FIG. 39.—TROCAR AND CANULA.

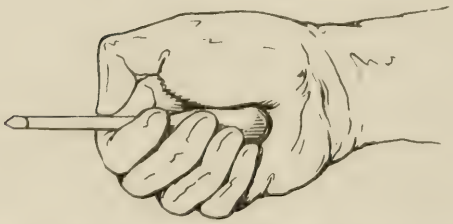


FIG. 40.—METHOD OF HOLDING TROCAR AND CANULA.

which they are transferred to similar solutions in 1 : 1000 bichloride of mercury. The bichromate tends to preserve the brushes.

Sand bags are cushions made of rubber cloth, filled with fine sand; and are used for supporting parts during operations and for maintaining positions of the patient. They are made in several sizes: 62 by 20 cm. (25 by 8 inches); 50 by 38 cm. (20 by 15 inches); 45 by 25 cm. (18 by 10 inches); 30 by 25 cm. (12 by 10 inches); 25 by 23 cm. (10 by 9 inches); and 30 by 13 cm. (12 by 5 inches).

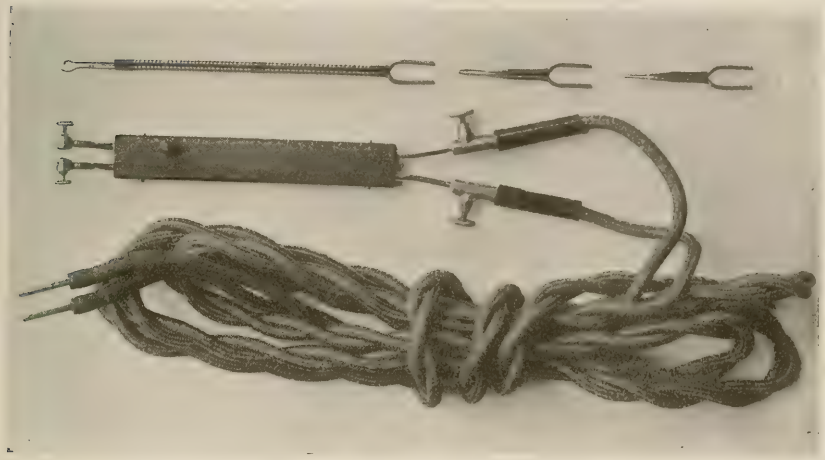


FIG. 41.—ELECTRIC CAUTERY.

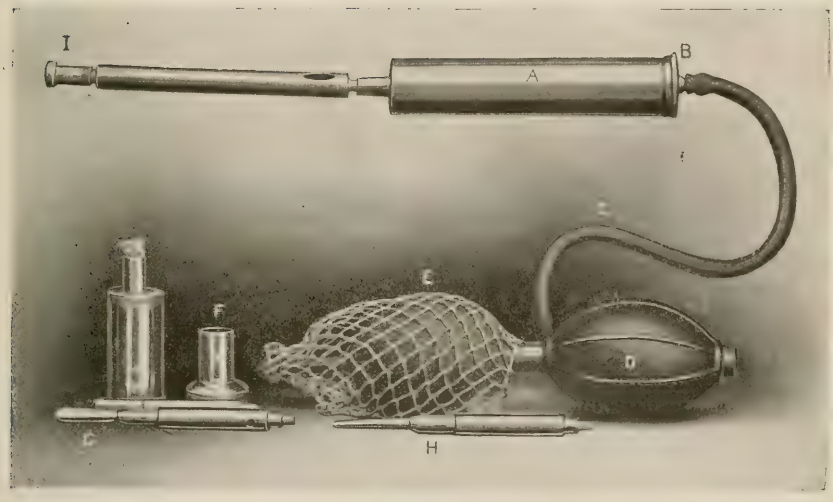


FIG. 42.—THERMOCAUTERY.

The hollow handle *A* contains absorbent cotton which is saturated with benzin. *B*, removable cap; *C*, rubber tubing; *D*, rubber air-pumping bulb; *E*, air-bag guarded by netting; *F*, alcohol lamp and cap; *G*, knife-shaped cautery tip; *H*, small pointed cautery tip; *I*, button-shaped cautery tip.

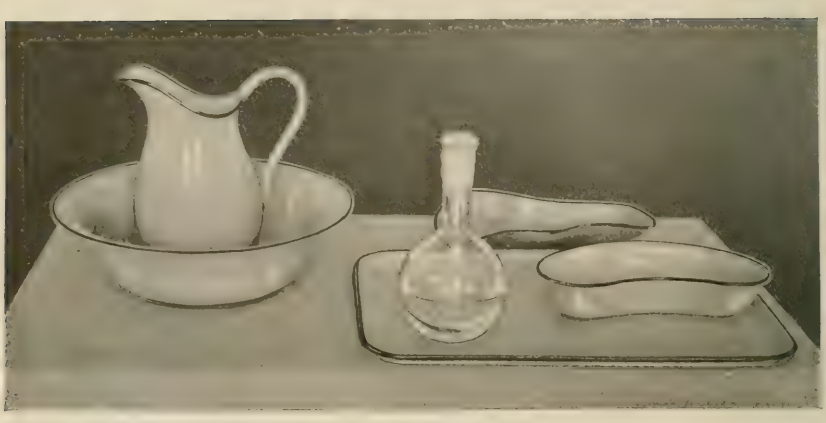


FIG. 43.—DISHES AND VESSELS COMMONLY USED IN SURGERY.
Hand basin, water pitcher, pus basins, flask, tray.

FIG. 44.—IRRIGATING JAR.

Operating tables should be as simple as possible. Good surgery can be done on the plainest table (Fig. 48). For convenience, tables allow of placing patients in the several positions best adapted for the various opera-

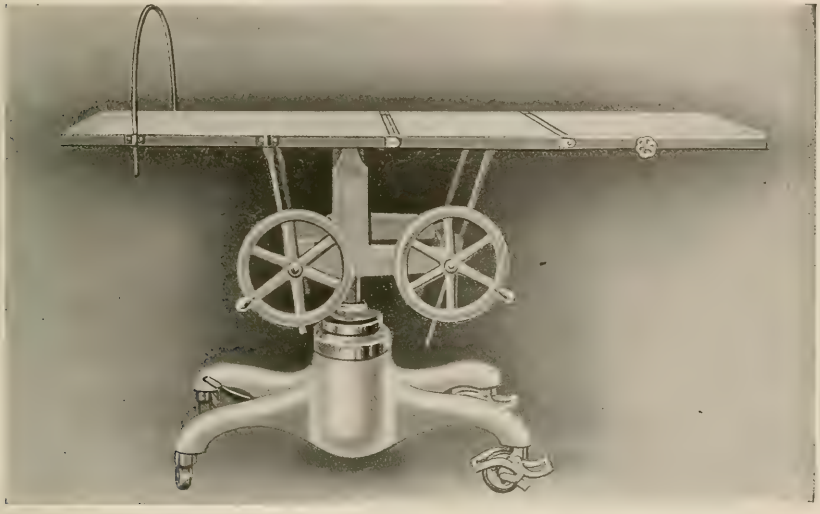


FIG. 45.—OPERATING TABLE.
Modern hospital type; capable of placing patient in several positions.

tions (Figs. 46 and 47). Besides this they should provide for carrying away irrigation fluids. The best tables are made entirely of iron enameled white

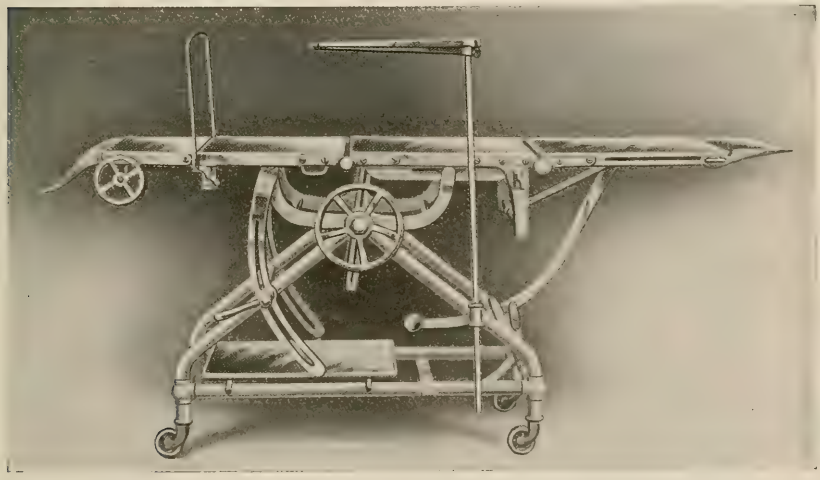


FIG. 46.—OPERATING TABLE, CAPABLE OF SEVERAL POSITIONS.
Showing instrument table attachment and frame for screen between field of anesthesia and operation.

(Fig. 45). Every part of such tables should be capable of being washed. Next to enameled iron tables, the best are made of wood. Glass tops are

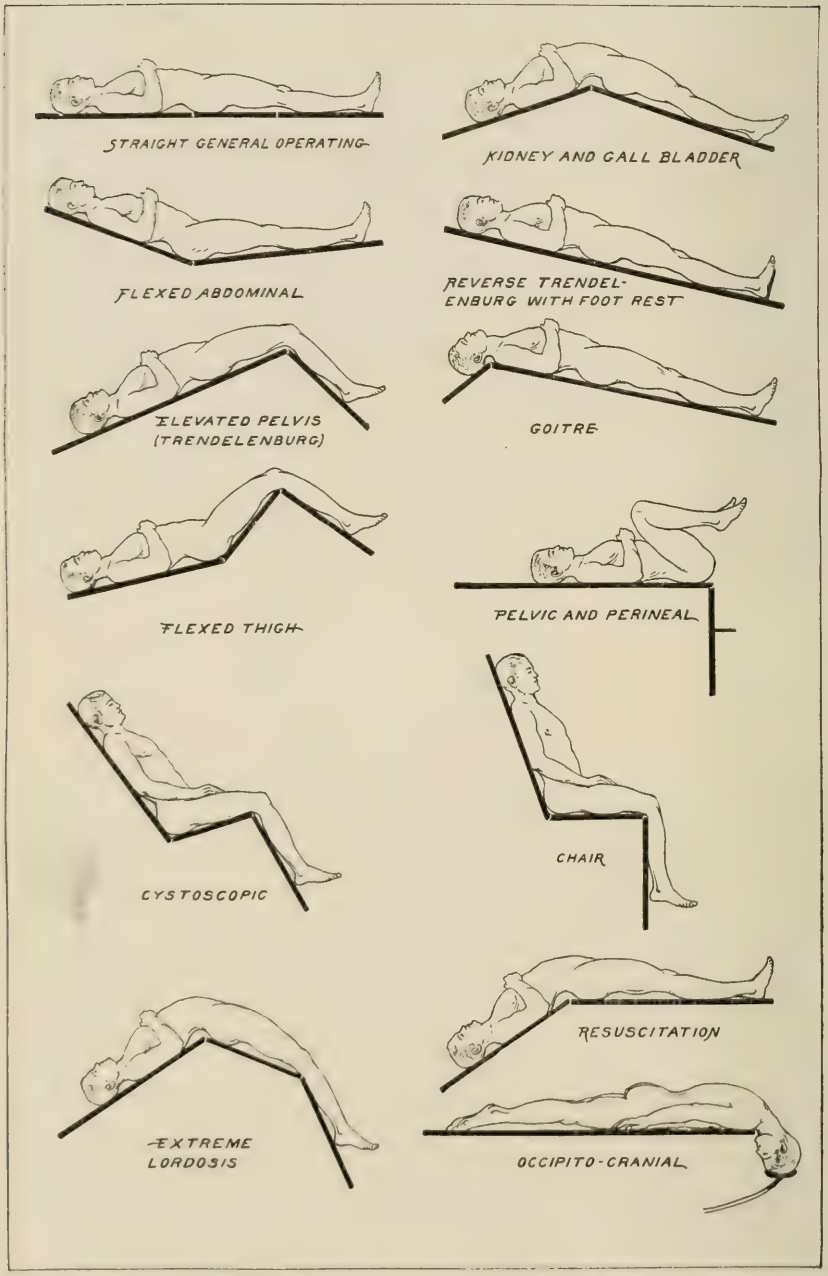


FIG. 47.—POSITIONS WHICH MAY BE SECURED ON A MODERN OPERATING TABLE.

very heavy and break easily. They have the advantage of not corroding, and are easily kept clean.

Special instruments and appliances are described in chapters dealing with special branches of treatment.

EMERGENCY INSTRUMENTS AND SURGICAL EXPEDIENTS

While there are special instruments and appliances devised for the surgeon, still emergencies arise in which these can not be had. Under such circumstances ingenuity must devise appropriate substitutes. Fire and water

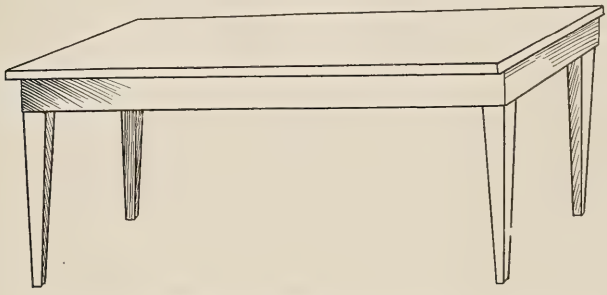


FIG. 48.—OPERATING TABLE.
A simple wooden table is entirely adequate for most operations.

are usually available for purposes of sterilization; and scrupulous washing and cleansing can be practised wherever water is to be found. The razor, a well-sharpened table knife, or pocket knife, have all lent themselves in the place of the scalpel. The scissors of the sewing basket answer admirably for

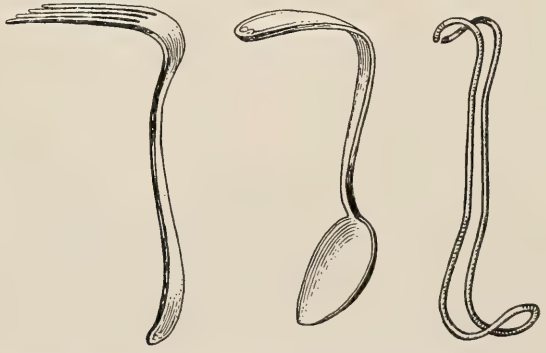


FIG. 49.—RETRACTORS EXTEMPORIZED FROM FORK, SPOON, AND WIRE.

surgical purposes. The fingers, a pair of tweezers, or a table fork to make tension serve the purpose of tissue forceps. For hemostatic forceps I have employed with much satisfaction a small pair of mechanic's pliers. A small hook may be used to pick up bleeding vessels for ligation.

Retractors may be extemporized from forks, spoons, wire or other metals, heated and bent into the desired shape (Fig. 49).

An admirable speculum may be made from a spoon. Cylindrical specula are made of bottles, metal tubes, or boxes. The ordinary sewing needles answer well for the surgeon. A curved needle is easily made by heating a straight needle, bending to the desired degree, and quickly plunging in cold water. Forceps or pliers from the tool chest serve as needle holders. Thread of cotton, silk or linen is perfectly sterilized by boiling. For ligating vessels silk is preferable.

Receptacles for containing irrigating fluids may be extemporized from any clean vessel if rubber tubing is at hand. A large bottle, with the bottom removed, inverted and the tubing connected through the mouth, serves very well (Fig. 50). Or the fluid may be conveyed out of a vessel by siphonage, a piece of bent wire (hair pin) being introduced at the bend of the tube to prevent its collapse (Fig. 51).

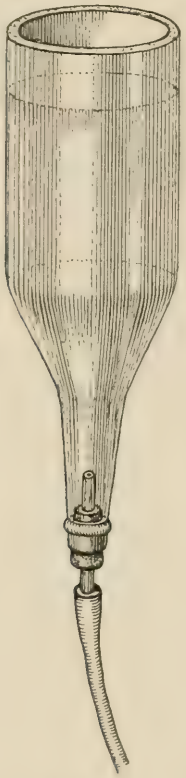


FIG. 50.—IRRIGATING JAR EXTEMPORIZED FROM BOTTLE.

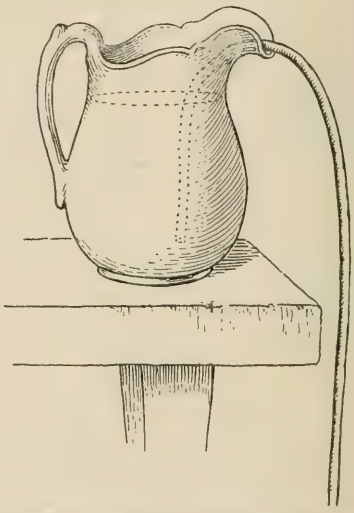


FIG. 51.—EXTEMPORIZED SIPHONAGE IRRIGATION.

For the emergency introduction of saline infusions such an appliance may be employed, or a rubber fountain syringe may be boiled and used. A simple funnel also lends itself for these purposes. In the absence of such irrigating facilities the fluid may be poured from a vessel or bottle directly upon the part to be irrigated. For an extemporized operating table, the ordinary kitchen table answers well (Fig. 48).

An emergency chloroform mask is made by wadding a handkerchief or piece of cloth in the bottom of a drinking glass or cup. An ether cone is extemporized by rolling stiff paper together into a cylinder and stuffing it partly with gauze or cloth.

A rod of iron heated in the fire serves as a cautery. Powder shakers are made of salt or pepper boxes. A curette is found in the hardware shops in a little instrument for taking the eyes out of potatoes. The lid of a match box has been used successfully for a curette. For an aneurism needle the ordinary large needle or probe can be used eye-first. Bobbins and buttons for intes-

tinal anastomosis are made from potatoes and carrots. Carpenter's forceps make a good angiotribe. For bone suturing the iron wire of the hardware store is better than the silver wire of the operating room. A thimble or a piece of steel wire can easily be converted into an ear or nose speculum.

Bone instruments are found in the hardware store in the form of chisels, mallets, drills, and metal plates. Joiners' saws, chisels, and mallets serve perfectly for bone operations. Cutters and pliers for bone work are also to be had at the hardware store. Bone can be drilled with a gimlet or a bit in a hand brace. A small piece of rubber tubing with the end smoothly rounded, together with plenty of olive oil, has been satisfactorily employed as a catheter. A filiform bougie is easily made from whalebone. A good "coin catcher" for extracting foreign bodies from the esophagus may be made of a silk catheter and a bent loop of wire. (Fig. 52).

FIG. 52.—"COIN CATCHER" EXTEMPORIZED FROM CATHETER AND BENT WIRE.

An aspirator or syringe can be made of a piece of rubber tubing. The air may be exhausted by compressing it between two rollers, by rolling it into a coil or by stripping it between the fingers. By reversing the process air can be compressed in it. Most anything that can be done with a syringe can be done with a piece of rubber tubing. A rubber catheter which is too large can always be made smaller by splitting it lengthwise and removing a longitudinal section.

For sponges and wound dressing material, any fabric which can be washed and boiled will serve in an emergency; it is immaterial whether it is cotton, linen, silk or wool. A large variety of materials which lend themselves for wound dressing purposes is described above (page 41).

THE CARE AND STERILIZATION OF SURGICAL INSTRUMENTS

For reasons of efficiency and economy surgical instruments should be well cared for. They should be protected from their three enemies: rust-corrosion, dirt, and bruising. Steel instruments should not be kept in the room where water is being boiled or where the steam sterilizers are located. They should be kept in glass cases which can be closed tightly. Some carbonate of soda, dehydrated lime, calcium chloride or other hydroscopic material may be kept in the instrument case. A hygrometer hung in the case to show the amount of moisture present in the air is also of service. Instruments kept in a mixture of crude phenol 3 parts, potash soap 3 parts, and water 100 parts do not rust.

Instruments are sterilized by boiling for five to fifteen minutes in water containing 1 or 2 per cent. of sodium carbonate. Crystalline soda should be used and not the kind adulterated with sulphates and chlorides. The object of the soda is to prevent rusting, to raise the boiling point of the water, and to assist in dissolving foreign material. The instruments should not lie against the metal of the bottom of the boiler, against which the heat is applied, as too high a heat injures them. They should lie in a wire basket which is lowered into the water, or they may lie upon some cloth placed in the bottom of the vessel.

Knives and fine needles, the edges of which might be dulled, should be boiled from two to five minutes. I have practised putting a small fine whet-

stone in with the instruments to boil, and using it to sharpen a knife as occasion required during an operation. Other cutting instruments such as chisels, scissors, etc., should not be boiled longer than five minutes. From the sterilizer the instruments are transferred to a dry sterilized cloth on the instrument table.

Hard rubber articles are injured by boiling. They may be scrubbed in warm water and soap, rinsed off, and placed to soak in 1:30 phenol or 1:1000 bichloride solution. Soft rubber articles may be boiled, but several boilings ultimately cause softening of the rubber. Rubber catheters are most economically sterilized by formaldehyde. Syringes made of glass or having accessory parts of asbestos or metal may be boiled; but if the pistons and washers are of leather, they should be taken apart, the glass or metal parts may be boiled and the leather parts washed with soap and water and immersed in 2 per cent. formaldehyde solution. The leather parts of syringes should be soaked in water occasionally to prevent drying, and a little oil should be applied. The hollow needles of syringes should have the water blown out and then the wire warmed and inserted. Treatment with vaselin will prevent rusting.

For transportation, instruments after being sterilized may be dried and packed in a box between the folds of sterile cloth. It is wise for the surgeon always to have on hand a few essential instruments ready sterilized, such as knives, scissors, hemostats, forceps, and needles. These may be kept in a closed glass fruit jar; and, together with suture materials and gauze which is kept in a sterile state, they constitute an emergency equipment.

As soon as possible after being used instruments should be cleaned, dried and put away. Those which have come into contact with septic material should be sterilized before being returned to their cases. Instruments should be washed in cold running water; a piece of gauze facilitates removing blood. They are then scrubbed with warm water and some washing powder until they appear thoroughly clean, rinsed and dried. The blades of knives should not be scrubbed with brushes. The edges should be kept sharp. They should not be put away for further use unless sharp; and it should be the duty of the instrument nurse to see to it that they are. They should receive stropping or sharpening on a stone whichever is needed.

To sharpen knives which are dull a paste may be made of fine carborundum powder (No. 1, F). This powder may be made into a paste with strained tallow. A little oil may be added when the paste becomes too stiff. The **carborundum paste** smeared on a piece of smooth leather on a flat piece of wood may be used as a strop, which will most effectively sharpen instruments. The knife should be held at right angles to the strop.

Scissors should be kept smooth and sharp and the joints not too loose. Saws should be set and sharpened when necessary. Needles should have a final washing in alcohol, be dried, and stored in lycopodium or gauze. They should be examined for dull points, and such when found should be either sharpened or thrown away.

All instruments having joints should be examined to see that they are in perfect working order. Syringes and aspirators particularly require such attention, the packing often becomes dry or contracts away from the barrel. The inside of hollow instruments, holes and crevices should be carefully cleaned by swabs on applicators or by wire brushes. Moisture remaining in the crevices of the chain saw or other instrument may be removed by holding above the flame of an alcohol lamp. Such complicated jointed instruments should be treated with vaselin or oil to prevent rusting.

Fountain syringes of rubber should be washed and hung up to drain and

dry. Rubber catheters and other rubber tubes should be cleaned with soap and water, rinsed, dried and kept in closed receptacles in talcum powder, as described above for the treatment of rubber gloves and bandages. Filiform bougies should not be boiled but sterilized by formaldehyd or washed and placed in 1:40 phenol solution.

Blood and foreign material should be removed from instruments because they may harbor spores of bacteria which would not be destroyed by boiling. Moreover, such foreign matter causes corroding and clogging of instruments and is a moral encouragement for the presence of dirt.

ANESTHESIA AND ANESTHETICS

Anesthesia is a condition of abolition of sensation. It is distinguished from analgesia which is a condition of abolition of pain. Anesthetics are agents which temporarily abolish sensation. They are represented by general and local anesthesia; the former being a state of total absence of sensation appreciation, the latter being a localized abolition of sensation in the peripheral nerves. These conditions are induced by the action of certain drugs and by mechanical interference with the sensation-transmitting power of centripetal nerves.

GENERAL ANESTHESIA

General anesthesia for surgical purposes is usually induced by the inhalation of the vapor of volatile liquids or gases which have peculiar anesthetic properties. As anesthesia is virtually a poisoning of the nerve cells, and as there are positive dangers in the anesthetic state, the period of anesthesia should be made as short as possible. Everything and everybody should be in readiness for the operation as soon as the patient is ready—preferably before the anesthetic is begun. The administration of the anesthetic should be in the hands of one particular individual who should give his whole attention to it, and if possible he should have an assistant.

The preparation of the patient is a matter of much importance. There should be a preliminary *examination* of the patient's whole body and particularly of his heart, lungs and kidneys. The presence of abnormalities or diseases and the nature of the operation to be performed should be communicated to the anesthetist before he begins with the anesthetic. The examination of the vital organs should have been made a day or two before the operation. The intestinal tract should be emptied of excess of food products. The stomach should be empty. The patient should have had no solid *food* for twelve hours, nor liquid food for four hours before the anesthetic is begun. This is to prevent vomiting at a critical time. The best way to accomplish this is for the patient for a few days to have eaten with especial care and moderation; sparingly of meat; no food which can not be masticated to a fluid; and no food swallowed until it has been chewed to a fluid state.

The amount of ether or chloroform required can always be lessened by giving a hypodermic injection of 0.01 to 0.02 Gm. (1/6 to 1/3 grain) of *morphine* and 0.0004 Gm. (1/150 grain) of atropin half an hour before the anesthetic. This is of value in the case of people who drink alcohol. These people take anesthetics badly, and large amounts are required to reduce them to a state of relaxation. Ether is particularly ineffective with them, chloroform is dangerous, and any anesthesia may produce respiratory or cardiac paralysis or be followed by pneumonia or nephritis.

For the nervous and timid or in cases in which it is desired to minimize the amount of anesthetic inhaled, an injection of morphin one-half to one hour before the anesthetic is very effective.

This preliminary medication is not indicated in all cases. It should be used only when a skilled anesthetist is to administer the narcosis. With the use of these drugs, there is greater danger of respiratory failure; the eye reflexes

are diminished; and the danger of pneumonia after operations on the respiratory tract is increased. Death from respiratory failure has followed the use of morphin even after the anesthetic has been discontinued. But a small amount of ether, following morphin, has caused respiratory paralysis.

Morphin should not be given to the weak, to the aged, to the cachectic, to the very young, to patients with fever, to patients with obstructive dyspnea

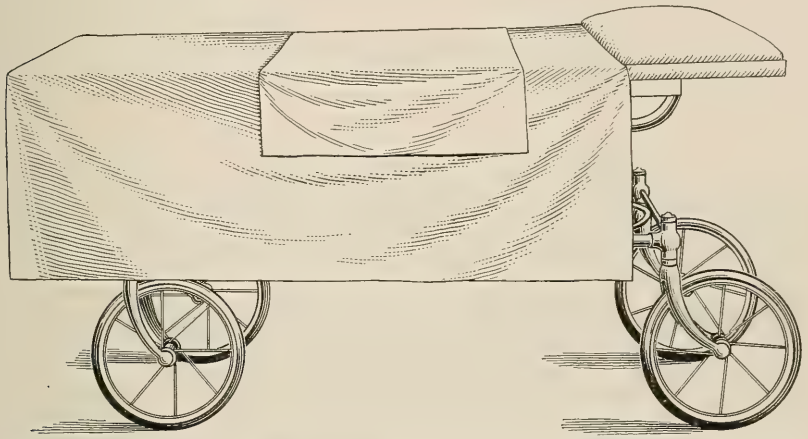


FIG. 53.—CARRIAGE FOR TRANSPORTATION OF PATIENT TO AND FROM OPERATING ROOM. Pad, blanket and folded sheet.

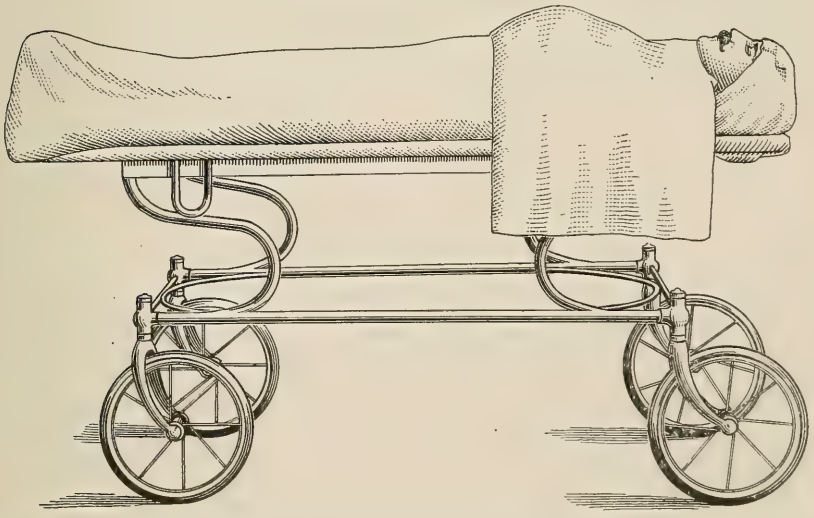


FIG. 54.—CARRIAGE WITH PATIENT.

due to pressure such as is caused by goitre or disease of the air tracts, to patients who are to have operations about the mouth or throat or other parts of the respiratory tract, nor to patients who are to have an inexperienced anesthetist.

The injection of morphin may wisely be used before all major operations in which the above contraindications are not present. It allays fear, prevents the stage of excitement, prevents pain after the operation, reduces the

amount of anesthetic required, and prevents shock. Atropin alone may be given when for any reason it is important to maintain a dry condition of the respiratory tract. None of these drugs should be used as a routine in all cases.

If the patient has habitually practised living hygienically it is better to omit the preliminary *purge*. Ordinarily, with a large amount of noxious material in the intestine, the patient should have a purge twelve hours before the operation, followed by an enema a few hours before. The patient's bladder should be empty.

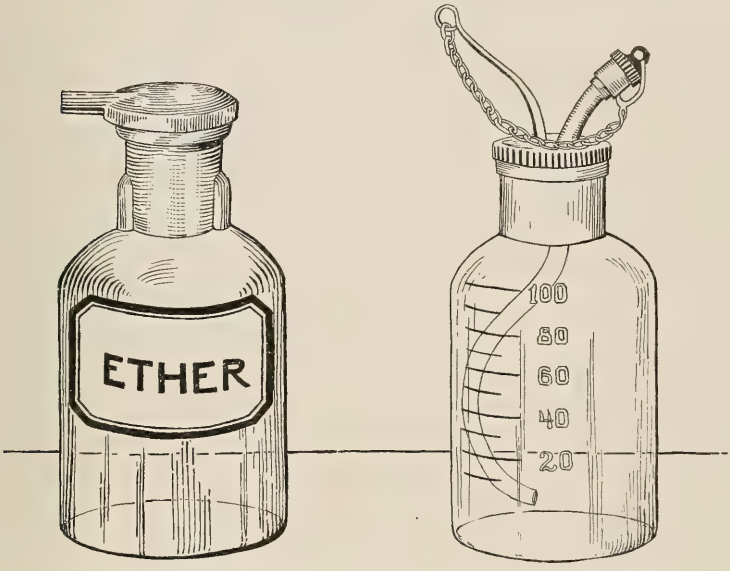
If an emergency operation is required upon a patient with food in his stomach the anesthetic must be given with great care. In some cases the stomach may be washed out or the anesthetic begun and the patient allowed to vomit. The enema should be given.

FIG. 55.—NARCOTIST'S MATERIALS.
Showing open mask, closed mask, ether can, basin, towel, tongue forceps, screw gag, hinged gag and sponge holder.

The *mental state* of the patient is of importance. Every effort should be made to inspire him with confidence and cheer, and to spare him from depressing sights and sounds. The anesthetist should approach him with confidence, and by no means be clothed in repellant raiment. If it is necessary for the anesthetist to wear a mask or any other extraordinary article of apparel, let it be put on after the initial stage of the anesthesia. The anesthetic may not be a serious matter in the mind of the surgeon but it is for the patient, and he should be given every consideration. Psychic shock is a real condition. The patient's state of mind determines his suffering and oftentimes the amount of shock which he is to sustain. It is best not to anesthetize a patient in an extreme state of mental excitement or depression with rapid and feeble pulse.

The *position* best adapted for anesthesia is with the patient lying on his back upon a firm flat surface. There is to objection to a thin hard pillow to elevate the head. An *anesthetizing cart*, a high, narrow bed on wheels, (Fig. 53) is best adapted for this purpose. It should be provided with a stretcher for lifting the patient. This can be wheeled to the side of the patient's bed and to the operating table (Fig. 54). The patient should be clothed in an *operation suit* (Fig. 23), a convenient form of which consists of a jacket, reaching to the middle of the thighs, with loose sleeves, opened in the back and fastened by tapes, operation stockings, and a cap.

The technic of general anesthesia should be made as simple as possible. There should be at hand, not to be seen by the patient, a tray containing an emergency equipment consisting of an hypodermic syringe which has been tested, a pair of *tongue forceps*, two *mouth gags* (a screw gag and a hinged gag, long sponge forceps with small sponges for removing mucus from the throat, towels, a small basin, and such drugs as may be necessary (Fig. 55). Another tray should contain the bottles (Figs. 56 and 57) for the anesthetic and inhalers, if liquid anesthetics are employed. The anesthetist should also have at hand a watch and a chart for noting the patient's pulse rate, etc. The curve shown by this chart furnishes a valuable record which the surgeon may glance at with profit (Fig. 58). Arrangements and apparatus may



FIGS. 56 AND 57.—BOTTLES FOR DROPPING ETHER AND CHLOROFORM.

also be at hand for making note of other phenomena such as blood-pressure, respirations, etc.; but the anesthetist should not be burdened with too great a diversity of duties. If he gives his anesthetic, puts down the pulse rate every five minutes and carefully watches the patient's condition, he has occupation enough.

Before beginning the anesthetic the anesthetist should speak a few words with the patient to secure his confidence. This may take the form of some inquiry, showing his interest in the patient, asking if he has ever before taken an anesthetic, and assuring him that he will not find it very unpleasant. A nurse should stand by the patient's side. The anesthetist should satisfy himself that the patient has no false teeth, tobacco, chewing gum or other foreign body in his mouth.

For the administration of anesthetics, inhalers, through which the drug is taken, are used. Liquids are poured on gauze, cloth or some surface from which it evaporates and the vapor is inhaled. Gases are administered from a rubber bag connected with the inhaler or directly from the compression tank.

As the anesthetist holds in his hand the inhaler he should explain to the patient that he will quickly become accustomed to it, and instruct him to breathe naturally through the nose or mouth, whichever he prefer, to cough

if he feels like it, lie quietly, close his eyes, and go to sleep. The inhaler without any anesthetic is then applied gently to the patient's face, and the same assuring instructions given in a quiet tone of voice. The patient is allowed to take a few breaths through the inhaler without any anesthetic; then it is added in the smallest possible amount, and slowly increased as the patient becomes accustomed to it. All the while, in most cases, the anesthetist may continue speaking in just an audible tone, to the patient, assuring him that he is taking it splendidly, that he will soon be asleep. "Just breathe along quietly; you are going to sleep; quietly, going to sleep, going to sleep; you are going—to—sleep."

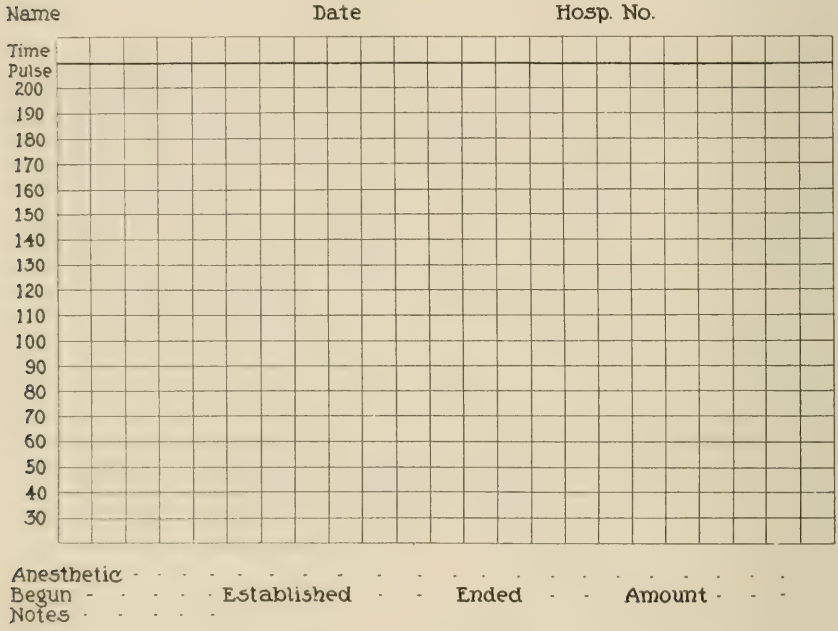


FIG. 58.—NARCOSIS CHART.

By a judicious application of the principles of suggestion, surrounding the patient with quietness and confidence, he may be anesthetized without passing through a *stage of excitement*. But if the anesthetizing room is pervaded by hustle-and-bustle, if the anesthetist goes at his patient too fast, if there is much display of paraphernalia or extraordinary arrayment, if the patient feels the nurse on one side and a husky orderly on the other gently but firmly grasp his wrists before his senses have become numbed, if he is repeatedly instructed to "take a deep breath," the classically described stage of excitement will be expected. The motto for the anesthetic room should be "Silence;" and the judicious employment of suggestion can be made the best ally of the anesthetic.

Ether and chloroform cause a slight sensation of choking or suffocation; The patient, unless under strong control of will, will often be prompted to remove the inhaler from his face. At this time he is quite conscious, and, if he persists in his objections to the anesthetic, the inhaler should be removed and he should be requested to coöperate with the anesthetist. Young children and persons lacking intelligence, of course, must be held at this time. The anesthetic should be continued steadily until the desired degree

of anesthesia is reached. The head should be rotated to one side to permit saliva and mucus to escape from the mouth.

There is a primary stage of anesthesia in which the sensations are numbed but in which muscular relaxation is not attained. Slight operations, such as the incising of an abscess, may be done at this stage. If the anesthetic is discontinued the patient quickly "comes out."

If the ether or chloroform is continued the state of *complete surgical anesthesia* is secured in from five to fifteen minutes. This is characterized by the system coming completely under the influence of the drug. The respirations become slower; the heart action, which at first is accelerated, becomes normal; the voluntary muscles relax; and finally the patient loses sensation reflexes. The muscular relaxation may be tested by flexing the elbow or other joint and finding no resistance. The loss of sensation is discovered by taking hold of the lashes of the upper eyelid and quickly lifting the lid. If there is absence of sensation this action will not be resisted by the depressor muscle. Another test of the *reflexes* consists in gently touching the eyeball outside of the cornea (or, what is better, blowing on it); the absence of eye-closing contraction shows the paralysis of this reflex; and complete surgical anesthesia is present.

The average time required to secure complete anesthesia with ether or chloroform is seven or eight minutes, with ether preceded by ethyl chlorid three or four minutes, and with nitrous oxid one or two minutes.

During the administration of ether or chloroform there are four things especially to be watched: the respiration, the pulse, the eye, and the patient's color.

The respiration should continue steadily and evenly at about the normal rate. It is often accompanied by a stertorous sound due to the relaxation of the palate, cheeks, tongue, and lips. This regular breathing may be disturbed by the falling back of the *tongue* so that inspiration is hindered. This can be brought forward by pressing forward the lower jaw so that it projects anterior to the upper jaw. Commonly the jaw must be held in this position. This is best done with the middle finger behind the angle of the jaw, leaving the first finger to feel the facial artery and the thumb to lift the eyelid. Some prefer holding the jaw with the thumb. Sometimes it may be held by engaging the lower incisor teeth in front of the upper incisors. The position of making pressure should occasionally be changed to prevent subsequent soreness. The tongue may be held forward by means of a round gauze tampon, held by straight forceps and passed to the extreme base of the tongue just above the epiglottis. Pressure forward is accomplished by leverage against the upper incisor teeth.

If these expedients do not bring the tongue forward sufficiently to make breathing easy the mouth should be opened and the tongue grasped with the tongue forceps. To prevent soreness of the tongue, if it must be held for more than five or ten minutes, a needle threaded with strong silk should be passed through it, transversely well back from the tip, tied in a loop, and the organ held forward with this. Too strong traction should not be made on the tongue as by so doing the epiglottis is held so widely open that saliva enter the larynx.

The accumulation of mucus and saliva in the throat should be removed by sponges on holders, which should be passed back to the pharynx with a gentle rotary motion, care being taken to inflict no damage upon the mucous membrane.

Sometimes the respirations become irregular, halting or suddenly cease. If the throat is clear of obstruction this is due to one of two things: either

too little or too much anesthetic. If due to too little, the patient will be found "coming out," the eye reflex will have returned, and there may be some muscular rigidity. More anesthetic is indicated.

If the patient has too much anesthetic the cornea will be found paralyzed, the muscles at the joints relaxed, the pupils dilated, and the patient's lips growing darker. All of these facts should be determined quickly. The inhaler removed, and respiration stimulated. Quick pressure over the chest should be made and the tongue drawn forward; this failing, the head should be lowered, and *artificial respiration* begun.

Artificial respiration on the operating table is best accomplished by the method of *Sylvester* or *Schäfer*. In the former the arms are grasped and drawn strongly upward and then carried down to the sides of the chest against which the flexed arms are pressed. The patient lies on his back. These motions should be made regularly at the rate of 24 to the minute. An hour or two is not too long to continue this operation if necessary (see Artificial Respiration, Vol. III). While artificial respiration is being practised the apparatus for intratracheal insufflation should be gotten ready, and employed as soon as it can be introduced, if breathing has not been resumed.

The pulse should constantly be under the observation of the anesthetist. He should not accept any arrangement of the patient upon the table which does not permit free access to a superficial artery. The pulse can best be felt at the wrist, at the facial artery just under the jaw, the temporal artery in front of the ear, or the coronary artery near the mucous membrane of the upper lip. At first the pulse rate is increased, but when the patient becomes anesthetized, the quality and rate of the pulse should continue about the same as it normally is for the individual under observation. If it becomes weaker the possibility of too much anesthetic should be thought of.

During the smooth progress of an anesthetic, if the patient begins to "come out," the first sign will often be increase of the pulse rate. Increase of pulse rate also precedes vomiting. Commonly during operations the irritation of nerve trunks, such as the phrenic, or peripheral irritation induced by the manipulation of strongly enervated structures such as the testicles, may cause changes in the cardiac rhythm. Loss of blood is distinctly shown by the pulse. Shock is manifested by the pulse.

When a weakening of the heart is not due to the surgical manipulations but to the anesthetic, it should be met promptly by temporarily discontinuing the latter, changing it for another anesthetic, or stopping altogether. *The wrong thing to do under these circumstances is to give stimulants.*

The routine hypodermic administration of "stimulating" drugs (whiskey, strychnine, nitroglycerin, digitalis, caffein, etc.) to these patients is one of the saddest sights to be witnessed in an operating room, being a relic of the fetish-worshiping belief in the potency of one poison to drive out or overcome another. If the heart becomes weak as a result of the poisonous effect of the anesthetic agent, there is one first thing to do: discontinue the anesthetic. By no means should it be assumed that there is any drug which can be injected into the patient which will neutralize the depressing effect of the anesthetic. If it can not be continued without a "stimulant," it should not be continued with one. If, on the other hand, the heart has stopped beating there is no stimulating drug employed by anesthetists that will make it resume beating. Fortunately what we often observe in the line of "stimulation" amounts to little more than cabalistic passes and motions: a hypodermic or two of whiskey, a dose of strychnia and digitalis of doubtful potency, usually are so immaterial as to have little or no effect one way or the other. What is more to the point, if the anesthetic is dis-

continued, the heart's action improves as a result of the patient's own vital resources and not as a result of any vital strength that has been injected into him.

For starting a paralyzed heart into activity, quick pressure over the precordium should be used, or deep pressure between the ribs over the apex. Blood should be sent to the cardiac centre by elevating the leg and lowering the head. Galvanism or faradism to the heart, and artificial respiration may be of use in stimulating cardiac impulses. The most effective means is by massage of the heart, the hand being thrust through an opening in the upper abdomen pressed against the diaphragm, and the heart compressed rhythmically between the diaphragm and the anterior chest wall at the rate from 15 to 60 times a minute. Massage has been applied successfully by the rapid division of two or three ribs, the turning back of a precordial flap, and, grasping the heart in the hand, making pressure from above downward, duplicating as nearly as possible the contractile motions of the organ (see Operations on the Heart, Vol. II). The best results have been secured by subdiaphragmatic pressure. In young children the chest wall is so elastic that external compression of the chest wall is capable of compressing the heart.

It is possible with rhythmic manual compression of the heart and with intratracheal insufflation to restore to life the apparently dead. The heart has been promoted into action after five minutes of recession.

The **eye,** particularly the pupil, is a valuable guide to the anesthetist in that he learns to look to it for much information as to the patient's condition. While it is susceptible to many changes and peculiarities still these can usually be recognized. Diseased eyes may give peculiar reactions, and the irritation of certain nerves such as those which affect the heart's action, may also influence it. Usually the pupil should look normal and react to light. Its failure to contract when quickly exposed to the light signifies too profound anesthesia. The dilated pupil usually means too profound anesthetization, weak heart, respiratory failure, or carbon dioxide poisoning from obstruction in the throat (tongue, mucus, saliva, or foreign body). A dilated pupil with an active corneal reflex generally means that the patient is coming out. In examining the eye care should be taken not to leave it exposed too much to the air, nor should the front of the cornea be touched with the finger lest an ulcer develop from the irritation. The effects of morphin, contracting the pupil, and atropin, dilating it, should be borne in mind if either of these drugs has been given.

The **color** of the patient should also be observed. This can be studied in the ears, lips, face, and fingers. Cyanosis indicates respiratory obstruction and carbon dioxide retention, or acute weakness and dilatation of the heart. Pallor is observed as a result of loss of blood, and the anesthetist may sometimes by virtue of this sign together with the appearance of the small and rapid pulse be able to advise the operator of the possibility of hemorrhage which is escaping the operator's attention. Heart weakness without superficial venous engorgement and lowering of blood-pressure, may both give pallor of the skin. The color of the blood in the wound shows if sufficient oxidation is going on; and the operator may call the attention of the anesthetist to it.

The **mortality** attributable to anesthetics is difficult to arrive at because anesthetics are given largely to diseased persons. Hewitt collected statistics of over 1,000,000 administrations in Europe. Out of 400,000 ether administrations, Guillard and Ormsby found a mortality of one in 16,000 cases. The chloroform mortality was one in 3162 cases. In warm climates the

chloroform mortality is much lower. The death rate for ethyl chlorid is about one in 3000 cases. A few deaths have been reported in connection with nitrous oxide, but Hewitt was able to find only seventeen in the literature extending over a period of forty years. No deaths are reported with nitrous oxide and oxygen. Ream reports 30,000 administrations without a single accident; and Teter reports no deaths in 12,000 cases, 1000 of which were for major operations. Gwathmey's American statistics from ninety-nine American hospitals, embracing 279,000 anesthesias, show the following mortality rate: ether, 1 death to 5623 cases; chloroform, 1 death to 2048 cases; chloroform-ether sequence, 1 death to 8027 cases; nitrous oxide with oxygen, 0 death in 8585 cases; nitrous oxide alone, 1 death in 1314 cases; ethyl chloride, 0 death in 905 cases; nitrous oxide with ether sequence, 1 death to 6905 cases. The American statistics show a much higher mortality than the European statistics because anesthetics have been given in America much more largely by unskilled and incompetent persons. Ether is so safe that it has been abused. It is so simple and safe that it has not demanded a skilled anesthetist. Nitrous oxide requires a skilled expert; and if it were given as much by the inexperienced as ether is, the mortality would be frightful.

Practical Points.—Anesthetics should be administered by skilled anesthetists. The anesthetist should get his training by watching, assisting, and receiving instruction with a skilled anesthetist. It is unfair to patients to permit anesthetics to be given by the unskilled. It should be permitted only in dire emergency.

To prevent the blistering effects of chloroform the lips may be smeared with vaselin before beginning the anesthetic. The position of the arms should receive the attention of the anesthetist as lying in one place for a long time or putting nerves or muscles on the stretch give rise to *traumatic paralysis*. Brachial paralysis develops from fastening the arms above the head and also from allowing an arm to hang over the edge of the table. The same dangers are inherent in positions of the limbs. Extreme flexion of the thigh causes paralysis of the sciatic nerve. The best position for the arms is folded easily across the lower part of the chest and held by the operation jacket being turned up over them and caught with a pin. Or they may be left lying on the table by the side of the patient.

The secretion of mucus in the mouth, excited by ether especially, can be minimized by a hypodermic injection of 0.0006 Gm. ($\frac{1}{100}$ grain) atropin. Often a patient will suddenly stop breathing and then resume respiratory motions of the diaphragm but keep the glottis closed. This is a sign that he is not thoroughly "under" and is about to vomit. This may be stopped by crowding the anesthetic a bit, but if not disconcerting to the operator it is best to withhold the anesthetic for a few moments and allow the patient to vomit.

Patients should be anesthetized with as little of the anesthetic as possible and have as much air with it as practicable. Care should be taken that the anesthetic does not drop from the bottle or leak through the mask upon the patient's face or eye. If a patient is to be restrained during the primary stage, the time to do it is before he gets up. The anesthetist should have exposed to his view as much of the face as possible. A towel over the eyes should be easily removable. The anesthetist should not permit anyone to put any weight upon the patient's chest during the operation. He should know just where his patient is—whether he is just under, moderately under, or deeply under the anesthetic. If he is not absolutely in touch with the degree of anesthetization he should discontinue the administration until the first signs of coming out appear and then resume.

Some patients do not take certain anesthetics well. If every care has been taken and the patient is not doing well apparently on account of the anesthetic it should be changed for another or discontinued. Rarely a person is found who can not take a pulmonary anesthetic.

The patient's heat should be conserved. It is the business of the anesthetist to see that the patient is properly covered and protected from cold.

During anesthetization the anesthetist should not talk with bystanders, nor is the surgeon justified in prolonging the anesthetic by engaging in time-consuming talks before or during the operation.

At the conclusion of the anesthetic if the skin is cold warm applications should be made. In applying hot water bottles it should be remembered that an anesthetized patient does not feel the heat and care must be exercised lest serious burns of the skin are inflicted. Patients should be placed in a quiet room and allowed to sleep after the anesthetic.

General anesthetics should preferably be given by a person with a medical training. It is a mistake to teach that the anesthetist should not look at the operation. He need not follow the detail of the operation, but he should know in a general way what the operator is doing. The manipulation of certain structures by the operator influences the breathing and heart action; there are certain procedures in which deep narcosis is necessary, and others in which no narcosis is necessary; the appearance of the blood is sometimes of significant importance; and the approach of the close of the operation should be known to the anesthetist.

The selection of the anesthetic can best be made by an anesthetist who understands what the operation is to be. He should be a better judge of this question than the surgeon. An anesthetist without medical training is apt to use a routine anesthesia for all cases. If the surgeon selects the anesthetic, the selection is made by one who is apt not to be an expert in the subject in which the judgment is given.

The use of restraint straps is undesirable if the patient knows they are being used. For alcoholics they are necessary. A strap with adjustable cuffs at either end is placed under the patient's thighs. He lies on this strap and the cuffs are adjusted about the wrists, the hands lying at the sides. A second broad strap is passed under the table and over the patient's knees. This suffices to restrain the most violent during the stage of excitement.

By keeping the patient's head rotated so that the face is toward the side, the saliva will run out of the mouth or will accumulate in the cheek and can be sponged out.

The anesthetic should be given uniformly. Most deaths occur in the hands of anesthetists who allow patients to approach consciousness and then plunge them again into deep narcosis. There is an effect on the blood produced by ether or chloroform which lasts for several hours. It is decidedly dangerous to etherize or chloroform a patient again soon after he has come out from the influence of one of those drugs. *Intermittent anesthesia* such as is used in operations on the face and mouth is decidedly dangerous, and should give place to narcosis by intratracheal insufflation, rectal anesthesia, or some other uniform narcosis.

The anesthetist should have available a tank of oxygen containing 8 or 10 per cent. of CO_2 to be inhaled by the patient in the event of respiratory stimulation becoming necessary. Or pure CO_2 may be diluted with 10 or 12 volumes of air.

As the operation is drawing to a close, the injection, into the rectum of

90 to 180 c.c. (3 to 6 ounces) of warm olive oil is of value to restore the opsonic index in cases of infection.

At the close of a prolonged general anesthetization, the vessels may be filled and thirst relieved by injecting into the rectum 500 or 1000 c.c. (1 or 2 pints) of warm saline solution containing 30 Gm. (1 ounce) of glucose.

Some surgeons have reported satisfactory results from shutting off the circulation in both legs or arms by means of a rubber bandage applied tight enough to occlude arteries and veins. This is applied before the anesthetic is given. At the end of the narcosis the bandages are removed and the fresh blood which is free from anesthetic and overcharged with CO_2, is liberated into the general circulation, with the effect of stimulating respiration and promoting rapid recovery. The method has been used especially in cases of kidney and liver disease. Some of the cases develop thrombosis, which it is conceivable might be serious.

Some of the psychic dangers of anesthesia may be overcome by *auto-anesthetization*. This applies especially to chloroform. The patient is given the mask and allowed to anesthetize himself; the surgeon standing aside and encouraging him with words of council and approval.

Children have much less resistance than adults. The loss of body heat is serious for the child. The anesthetic should be given in a warm room. Chloroform is very dangerous, and ether must be carefully given.

Children require a tactful as well as skillful anesthetist. There is no objection to anesthetizing a child in its nurse's or mother's arms if the alternative is to hold it screaming with fright on the table. Operations should be timed so as not to interfere with the child's nap. Before beginning the anesthetic 25 per cent. essence of orange or spirits of cologne may be dropped on the inhaler. If this is continued for a short time the child will learn to like it and the sense of smell will become numbed to the anesthetic which should gradually follow.

If advisable, it is possible to chloroform a sleeping child. A very small amount is dropped on the mask, and held nearer and nearer the child's nose. If the child moves the mask is carried away, and gradually returned when it becomes quiet. To discover whether the child is under, ether may be dropped on the mask and the evidences of irritation of the nasopharynx observed. The most simple general anesthetic for children is essence of orange or cologne spirits followed by ether by the drop method on an open mask. A skilled anesthetist may use nitrous oxide.

The anesthetist may proceed as follows: The vaporizing bottles of Gwathmey may be used. Essence of orange to the amount of 4 c.c. (1 dram) is placed in the water bottles. Nitrous oxide is given and in fifteen seconds the patient is unconscious. Weak ether vapor is pumped into the gas bag and the child allowed to rebreath the gas and ether till deep narcosis is secured. The gas bag is then laid aside and ether administered by the vapor method. This may be given with a mask or through tubes carried to the pharynx. For throat operations the vapor method, through tubes passed in the nares almost to the glottis, is useful.

Of all of the methods for children, the simple open-mask drop method with ether is most satisfactory.

Contraindications.—General anesthesia is contraindicated in operations upon persons *in extremis*. Persons suffering with the *status lymphaticus* take anesthetics badly and with great hazard. Serious uncompensated valvular disease of the heart is a contraindication, also tumors or diseases of the neck causing serious pressure upon the nerves and vessels, large tumors of the abdomen interfering with respiration and circulation, acute nephritis, pro-

found shock, and recent cerebral apoplexy. The closed inhalers are contraindicated for the obese; they should have ready access to air.

Choice of Anesthetics.—The safest and most easily administered anesthetic for general use is pure sulphuric ether, chloroform requires much skill and great care to avoid its dangers.

Ether increases the blood-pressure, chloroform lowers it; ether is a cardiac stimulant, chloroform is a cardiac depressant. Chloroform is a much stronger poison than ether. Ether irritates the respiratory mucous membrane. It is impossible for a healthy person to get a poisonous dose of ether in two or three inhalations of the vapor mixed with air; but it is with chloroform. Chloroform must, therefore, be given in smaller amounts and mixed with more air. Ether is preferable for the ordinary healthy individual. It is less desirable than chloroform in persons with irritated or inflamed respiratory tracts, or in high arterial tension, or in arteriosclerosis, or in persons with weak arteries. Its irritating effect upon the kidneys is probably greater than that of chloroform. Chloroform requires more skill, experience, and watchfulness in its use. For ordinary use, ether given by the drop method in an open inhaler has the widest applicability as a pulmonary anesthetic.

The routine use of chloroform for major operations is not justifiable except in warm climates. It may only be used when no safer anesthetic is to be had. It is to be preferred in skilled hands for old people with high blood-pressure and in children for short operations. In warm climates or in an operating room having a temperature of 39° or 40°C. (102° to 104°F.) it is to be preferred to ether.

For short operations, the safest and most satisfactory anesthetic is nitrous oxide and oxygen, administered by an experienced person. By utilizing rebreathing, to give the benefit of carbon dioxide when necessary and to conserve the body heat, by combining a little ether when indicated, and by heating the gases before they are inhaled, this combination represents the modern advancement in narcosis.

Warm versus Cold Anesthetics.—The dangers of ether and chloroform are reduced when administered out of doors, and still more reduced when given in warm climates. The reason for this is that the volatility of these agents is thereby increased. More anesthetic is used but the patient gets less. I was particularly impressed with this fact when doing operations in an operating tent in the warm air of Florida in 1898. Under these circumstances the chloroform hazard seemed to be quite eliminated. Some surgeons have made chloroform safe by raising the temperature of their operating rooms to 40°C. (104°F.) and increasing the moisture in the air.

The actual warming of the anesthetic is practicable though it complicates the administration. It is best not to attempt to warm ether in the fluid state as it boils at about 34°C. (93.2°F.) and rapidly looses its heat. When it is given by the vapor method, the vapor is pumped through water, and then the ether vapor and water mixture may be subjected to heat by passing it through a tube surrounded by heated water or better by an electric resistance coil. The same may be done with nitrous oxide. Chloroform which boils at 65°C. (149°F.) may be heated in its fluid state up to that temperature and then the vapor passed through the heating apparatus on its way to be inhaled. The temperature at which these vapors may with best advantage be employed is about 40°C. (104°F.).

Heated anesthetic diffuses more readily, is absorbed more quickly, extracts less heat from the body, and is taken in more finely mixed with air. I have given this method a fair test, and find that patients go under more comfortably, show less depression, and have decidedly less of the

unpleasant after-effects. At the completion of an operation, by having the patient breath warmed air, recovery from the anesthetic is more rapid and less complicated. With insufflation, with warm air, the anesthetic can be washed out of the lungs with great rapidity when necessary. Altogether the pulmonary anesthetization which approaches nearest to the ideal is, perhaps, warmed nitrous oxide and oxygen. The advantages of warming anesthetics are not sufficient to make the application of this principle practical, and it is destined to be but little employed.

Treatment of After-effects.—After the ordinary administration of ether or chloroform there is often a considerable degree of malaise and nausea. This is minimized, if the patient is in a healthy condition if there is a minimum of ptomain-laden material in the intestine, if the stomach is empty, if there has been a small amount of anesthetic given, and if the pharyngeal irritation from the anesthetic has not excited the secretion of much mucus which goes into the stomach, carry the irritating anesthetic with it. Of this latter condition there is always more or less—most with ether—and it is the presence of ether-laden mucus and saliva in the stomach which causes much of the nausea following this agent. This can be overcome by keeping the head turned to one side to permit saliva to run out of the mouth, and by washing out the stomach immediately on discontinuing the anesthetic and while the patient is still under its influence. Lavage may be practised as a routine measure or it may be employed particularly in cases in which the straining of vomiting would do damage. Nausea may be diminished by removing cloths and clothing from the patient having the smell of ether or by substituting some other smell such as cologne. The preliminary injection of morphin and atropin tends to minimize this vomiting. A patient under an anesthetic or coming out from an anesthetic should never be left alone—not until he has regained consciousness. He may choke or in the anesthetic delirium do himself damage.

The anesthetic which still remains in the blood and the tissues may be eliminated by promoting diuresis, keeping the body warm, and increasing the amount of body fluids. Patients who are exposed to the outdoor air to recover from their anesthetic have the least anesthetic nausea. If they must recover indoors, the air in the room should be in motion and constantly changed, as rebreathing and smelling the vapor of an anesthetic promotes nausea. The smell of the anesthetic may be disguised by dropping oil of bitter orange peel in gauze held at the nostrils.

ETHER

The ether used for anesthetic purposes is ethyl ether ($C_4H_{10}O$), a colorless liquid, made by distilling alcohol with sulphuric acid. It boils at 34°C. (93.2°F.) at sea level. Its low boiling point and great volatility make it about impracticable in warm countries and in high altitudes. It should be kept in an opaque vessel. Ether is highly inflammable, and the vapor burns readily. It should never be given within 8 meters of a naked flame. The vapor is heavier than air, and falling to the floor may find its way to a flame and cause an explosion. The actual cautery should not be used in its presence. In the process of manufacture a number of foreign materials, which are poisonous, irritating, and less volatile, are formed. These are called *fusil ethers*, and are found in most of the ethers made. The safest ether is free from these products. By pouring ether upon a clean surface of plate glass and allowing it to evaporate the fusil ethers may be seen as an iridescent residuum.

Ether is a cardiac stimulant. Evaporating so easily, when its vapor enters the lungs and encounters the body temperature, it expands and fills the alveoli, producing an artificial emphysema. It is very diffusible and easily passes into the blood and out again. But this means it shuts out oxygen and hinders the elimination of carbon dioxide, producing a certain degree of cyanosis which is often present throughout its use. There is a congestion in the vessels of the head and neck, and for this reason it is of disadvantage in inflamed conditions near the larynx on account of the danger of edema of the glottis.

It is the most easily administered and safest anesthetic in the hands of the less experienced. A healthy person who receives a sufficient amount of air with pure ether is in practically no danger. In the hands of an expert it can be given in most any case. Certain sensitive persons who have once had an unpleasant experience with ether will not take it, and they should be given some other anesthetic.

In giving ether, the patient should not be antagonized. He should have his own way, and be encouraged by the coöperation of the anesthetist. The anesthetist should employ sympathy, coöperation, and suggestion as the important adjuncts to the ether.

The primary effect of ether on the system is to cause a transient stimulation similar to alcohol. It then causes paralysis of the nervous system. First the higher centers, then the cord, and lastly the medullary centers are affected. The local action on the mucous membrane of the larynx first causes some spasmodic action of the throat muscles and reflex inhibition of respiration, which pass away as the anesthetization is continued. In this early stage the patient may stop breathing but resume breathing again when he is given more air.

Ether at first raises blood-pressure, but all the while it is given it is producing vasomotor weakness. Although the heart action may remain good throughout the administration, the more ether that is absorbed the greater will be the vasomotor depression after the operation. The primary stimulation of respiration caused by ether produces overoxygenation of the blood and reduces the amount of carbon dioxide to such a degree that respiratory paralysis is always threatened.

The pupils at first dilate, during the stage of excitement. Then they contract. They should contract still more when exposed to light. If they do not react to the stimulus of light it may be assumed that too much ether is being given.

During the early stage of the anesthetic, before muscular relaxation occurs, hallucinations are often present. The patient thinks his senses perceive things which are not present. He may shout, sing, swear, or become violent. On account of these hallucinations patients should not be anesthetized by the surgeon alone, as after the operation they often believe and assert that things were done which did not transpire. Also, as the effects of the ether are subsiding, the patient often passes through the same stage of mental excitement and becomes noisy and violent.

As ether vapor irritates the mucous membranes when used in high concentration and as it paralyzes the muscles and sensations of the trachea and larynx, coughing to expel inhaled saliva and mucus is inhibited. This gives rise to the danger of aspiration pneumonia. Ether should not be used on the unconscious patient in a concentration greater than can be borne by a conscious person without causing coughing. This is about 6 to 7 per cent. of ether vapor. The closed method of giving ether is objectionable because this percentage of ether vapor is apt to be exceeded, and the open method for this reason is highly preferable.

The patient's eyes should be covered with a pad of wet gauze or cotton when ether is given by inhalation. If the position of the head is such that the moist pad does not remain in place, a piece of gutta-percha tissue may be used instead.

Ether may be dropped from the ordinary 120-c.c. (4-ounce) can. A cork having a notch cut in either side, one for the admission of air and the other for the escape of the ether, answers admirably. It works better in the drop method if a small wick of cotton is passed through the outflow opening.

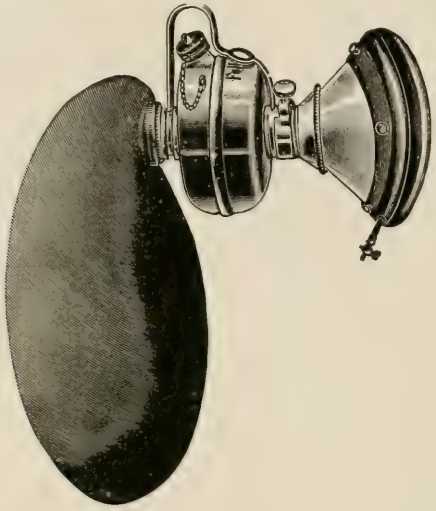


FIG. 59.—CLOSED ETHER INHALER WITH BAG FOR REBREATHING.

The rule should be to give as little ether as is possible to accomplish anesthesia. It should be borne in mind that it is the amount of ether which the patient inhales that causes anesthesia, and not that which is poured on the mask. There are several methods of administration.

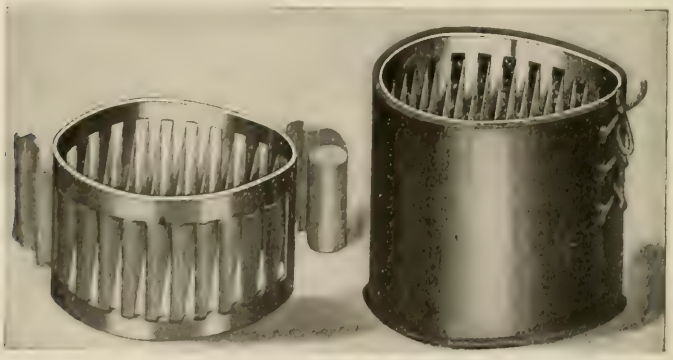


FIG. 60.—ETHER INHALER OF ALLIS. (*G. R. Fowler.*)
Showing metal frame with muslin bandage and frame covered ready for use.

The **closed method** of giving ether is by a cone which confines the air and ether vapor. The patient rebreathes much of the last exhalation. By this method a cone or mask is used which fits the face rather closely; fresh air leaks through the mask and around its edges. A bag attachment is often employed (Fig. 59). The patient has a disagreeable sense of suffoca-

tion. The anesthesia is combined with carbon dioxide medication by this method. This method is to be used only as an emergency expedient when the amount of ether available is limited and must be husbanded.

The **open drop method** is most commonly employed. It is the safest and simplest. Many types of open masks are used. They are characterized by being freely pervious. The ether is dropped upon an absorbent fabric in the mask. Inhalations draw through the mask the outside air which takes up the ether vapor on its way and conveys it to the lungs. Exhalations throw back by the same path the expired air, which, charged with ether vapor, permeates the environment.

The inhaler of Allis is very useful and economical (Fig. 60). The double mask is much employed. It has an air space between two layers of fabric. The simple wire mask of Esmarch is useful (Fig. 61).

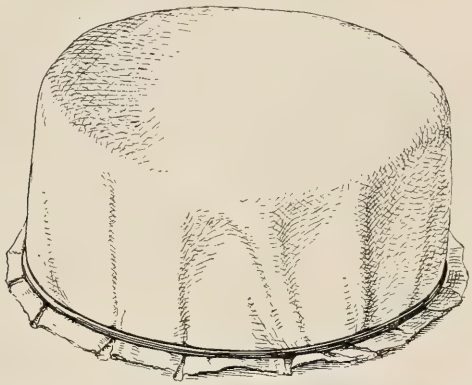


FIG. 61.—SMALL WIRE MASK INHALER USED FOR ETHER OR CHLOROFORM.
The frame is covered with tricot or several layers of gauze.

The best inhaler for the open drop method consists of a simple wire mask covered with two layers of stockinet or tricot (Fig. 62). This should be sterilized fresh for every patient.

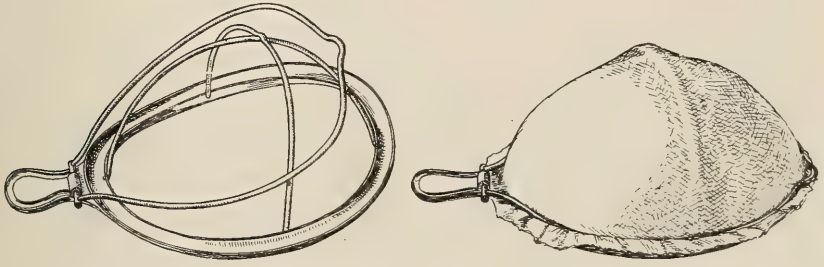


FIG. 62.—SIMPLE WIRE ETHER MASK FOR OPEN DROP METHOD.
The wire frame is covered with two layers of tricot cloth or stockinet.

By the open method ether may be administered by drops and the dose regulated. At first it is poured on drop-by-drop; then as the patient becomes used to it 2 Gm. (½ dram) or more are poured on; and then as the patient becomes anesthetized, the narcosis is maintained by about one drop for every inspiration. The patient does not have the depressing sense of suffocation, as fresh air is freely mixed with the vapor.

The mask should be held about 2 or 3 cm. (1 inch) from the patient's face. The ether is dropped upon the mask slowly and the patient asked to

breathe naturally through the nose. As the patient becomes accustomed to the effect of the ether the mask is gradually lowered, and the ether dropped faster. Not so much as to cause a sense of suffocation should be given. The mask at first occasionally should be lifted off entirely and the patient allowed a full breath of air. The patient feels a sense of tingling numbness in the extremities, swallows frequently, and the face becomes flushed. These are the signs that the drug is taking effect. At this stage a strip of three thicknesses of gauze about 1 meter long is wrapped partly around the mask. The ether is given a little faster and then the gauze is wrapped completely around leaving a small space for air to pass in and out. The method then approaches nearer the closed method, except that the interstices of the gauze permit better access of air and the drop method is continued.

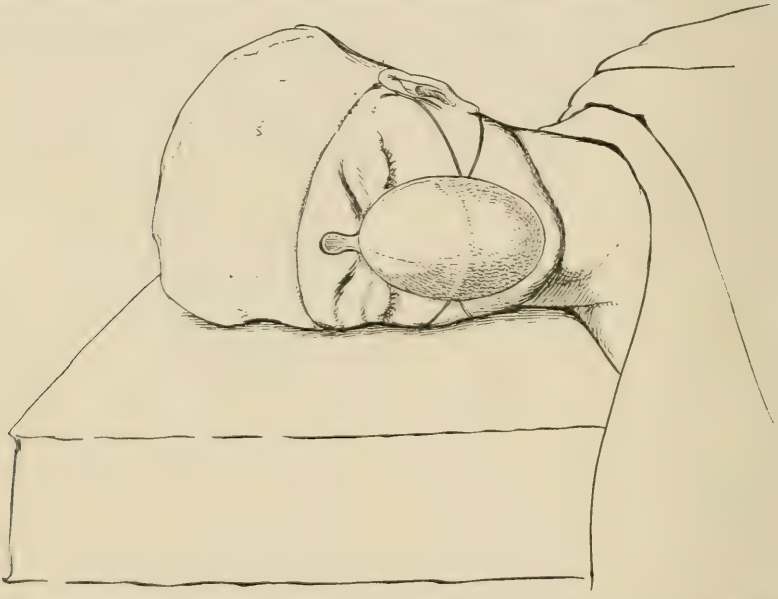


FIG. 63.—METHOD OF HOLDING MASK WITH RUBBER BANDS IN OPERATIONS REQUIRING LATERAL POSITION OR MUCH MOVEMENT OF THE HEAD.

If the ether is given too fast the patient will enter upon a stage of excitement. If this occurs the ether should not be crowded, but the mask should be removed and the patient given more air. Florence Henderson, who perfected this method at the Mayo Clinic, demonstrated that if the anesthetic is properly administered, and the patient is given only the amount of ether that he can take comfortably, there need be no stage of excitement.

The head should be turned to one side as soon as the jaw relaxes. The jaw should be held forward and upward. Surgical anesthesia may be secured by this method in from three to seven minutes. If the jaw is kept forward, and enough air is admitted with the ether vapor, the patient's color should be good during the operation.

The mask may be held by a string or elastic band passing from its side and looped about the patient's ear as the head is rotated to the side (Fig. 63). This allows the anesthetist to have his hands free.

Combined closed and open method is practised by covering with a rubber sheet, with a wet towel, or packing with gauze a cone used in the open method. This is satisfactory and effective in the hands of an ex-

perienced anesthetist. The open method first is used; then to reduce the patient to complete anesthesia the closed method is employed; after which the two are alternated or modified as the case may require.

It is practically the combined method when a closed cone is used which does not fit the contour of the face, as when a cup, metallic funnel, or a stiff hat is employed.

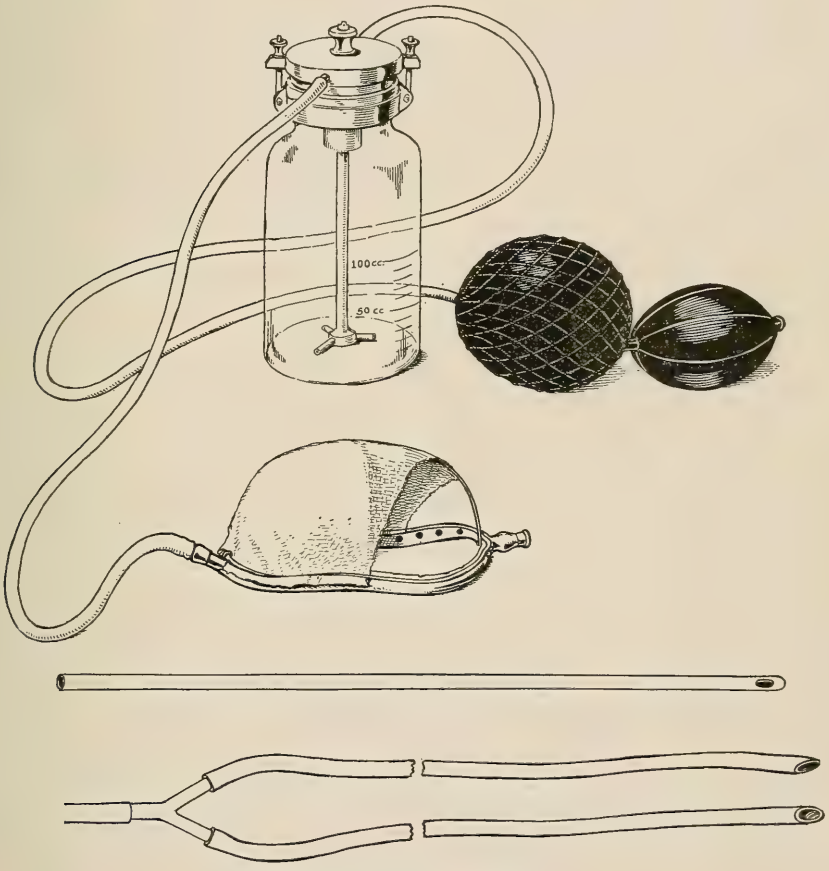


FIG. 64.—VAPORIZING BOTTLE.

Air is driven through the ether or chloroform, and carries to the mask or tubes a rich anesthetic vapor. Oxygen or compressed air may be used from a tank, or a foot bellows may be employed instead of the hand bulb pump. Instead of the mask, a catheter or rubber tubes may be connected and passed to the pharynx.

The **vapor method** consists in pumping air or gas through ether, or nebulizing the ether and conducting it in a tube to the respiratory tract (Fig. 64). Oxygen, nitrous oxide, carbon dioxide, or air may be used. A compact set of four bottles is made for this purpose. Two bottles contain ether; one contains chloroform; and the other may be empty to catch any overflow. The bottles may be kept warm in a warm air bath so that warmed ether vapor may be used.

The simple one-bottle vapor method is best adapted to chloroform, as it is often difficult to administer enough ether by this method.

It is effective if the ether is warmed by placing the bottle in a heated receptacle, and the vapor is pumped to the pharynx. A very useful one-bottle ether device may be made by attaching an atomizer to the efferent tube so that the ether is nebulized as it enters the tube.

The anesthetic vapor may be conveyed to a mask or by tubes to the pharynx. J. E. Lumbard devised a useful nasal tube of glass which is curved to fit the nostrils (Fig. 65).

For conveying the vapor to the pharynx or trachea in the case of operations about the face, mouth, or larynx, I have devised a simple cone in the form of a funnel which allows the mask to be held at any distance or position away from the face (Fig. 66). This apparatus may be used with nasal tubes passed to the pharynx, or with a tracheal tube.

For pumping air by the vapor method the rubber hand bulb pump, such as is used in connection with the benzin cautery, or a foot pump bellows may be used. The latter is most effective for nebulizing ether. Or compressed air or oxygen may be employed.

For conveying the vapor to the pharynx a rubber tube may be passed into each nostril. It may be fixed with a safety pin so that it shall not slide further in than is desired. This method of *pharyngeal insufflation* is very useful.

Confined vapor is applied through a rubber gas bag. The apparatus combines a cone for the face, a drop-method receptacle, and a gas bag. The ether vapor from the cone is inhaled. The exhaled air goes into the gas bag instead of into the free air. Here in the bag it accumulates, and by a simple device is caused to be rebreathed, so that with each inhalation the patient gets some fresh air and ether and some rebreathed air and ether. Oxygen may be admitted to the bag at will, and an electric heating attachment allows heating the vapor.

The **primary anesthesia method** permits short operations. There is an early anesthetic stage which lasts three to five minutes before full anesthesia is developed. It may be taken advantage of in the following manner in the case of a healthy person: The patient lies on his back on the table. A closed mask is used. It may be a simple wire open mask, covered with a sheet of rubber, and containing a mass of gauze. The patient is shown the mask, and the proceeding is explained to him. The gauze is saturated with ether, the patient is told to hold up his hand and breathe deeply. The mask is applied to the face. By the time he has taken ten or fourteen deep breaths his hand drops, and an operation, such as incising an abscess, may be performed. In a few minutes the patient wakes up confused and smiling, and is surprised to learn that the operation has been done.

It is possible for a skilled anesthetist to prolong this primary ether intoxication to an hour or more, the patient never going fully under the influence of the anesthetic, but lying partly numbed, in a confused state, mumbling, and moving his head, yet still narcotized sufficiently for major operations.

Oil-ether rectal anesthesia has superseded the vapor method by rectum. The absence of apparatus permits the anesthetist to give his entire attention to the patient. The method was introduced by J. T. Gwathmey, of New York, in 1913, after experimentation upon animals (American Jour. of Surgery, July, 1914). Among other facts discovered, it was found that colon bacillus is killed in one minute by a 75 per cent. solution of ether in olive oil; and by a 50 per cent. solution in ten minutes. When ether and olive oil are injected into the rectum, the physiological process is quite different from that of inhalation anesthetization. The mixture becomes heated by the body.

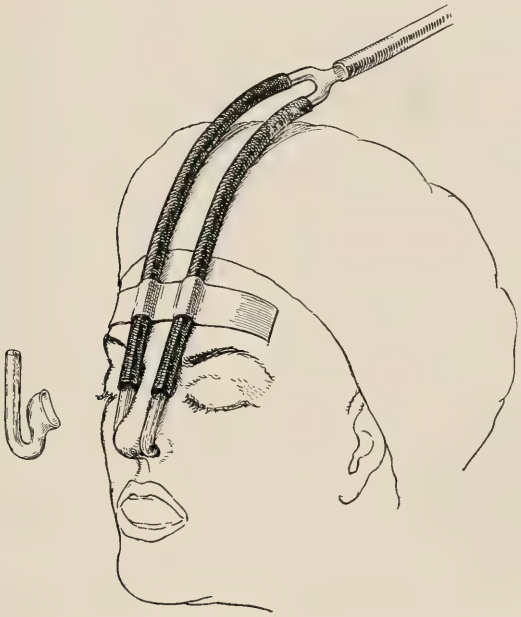


FIG. 65.—LUMBARD'S GLASS NASAL TUBES FOR ANESTHESIA.

This apparatus serves especially well for operations about the mouth. It may be used with the vaporizing bottle or with a closed mask. The tubes are easily introduced and cause less traumatism than a catheter or other tube which is passed to the pharynx.

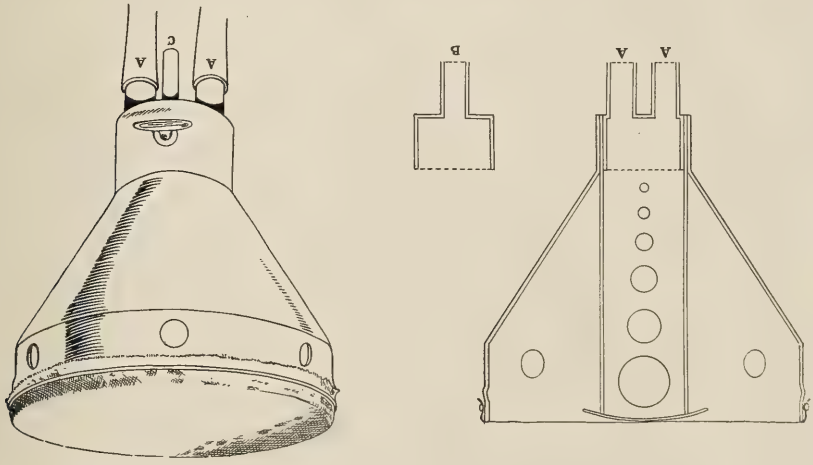


FIG. 66.—AUTHOR'S CONE VAPORIZER FOR CONNECTION WITH RESPIRATORY TUBES.

One tube may be detached and the patient allowed more air; an oxygen tank may be connected; or the openings may be covered and less air allowed to enter. *A*, For connection with rubber tubes to nose; *B*, for connection with single tube to trachea; *C*, for connection with oxygen tank or anesthetic vapor.

Some of the ether is liberated from the oil in the form of gas. It is absorbed into the small capillaries about the colon and conveyed in the blood to the liver, thence by the greater circulation to the heart, and finally to the lungs. By this time it has become warmed to the body temperature. It is exhaled through the lungs. Some of it is reabsorbed from the air passages. The odor of ether can be detected in the patient's breath in from three to four minutes after the injection is given. The colon absorbs the ether faster than the lungs can eliminate it. Anesthesia is made possible by the presence of the residual air in the lungs.

This represents the use of warmed anesthetic in its ideal form, as it reaches the lungs at body temperature. Stertorous breathing means too much anesthetic. Cyanosis indicates an overdose or an obstructed air passage. The muscular system is relaxed early, even while the reflexes are present. The face is not flushed as is the case with inhalation etherization. Consciousness returns while anesthesia is still present if morphin has been used in connection with the ether. The rate of liberation of the ether in normal individuals is constant. When fever is present a smaller amount of ether should be used.

The apparatus required is a rectal tube 1.3 cm. (½ inch) in diameter and about 50 cm. (20 inches) long, a clamp for the tube, an 8-cm. (3-inch) glass funnel, and a double tube for washing out the bowel. For the latter purpose two rubber catheters may be used.

Thirty c.c. (1 ounce) of castor oil should be given to an adult the evening before the operation. In the morning the bowel should be washed out until the fluid returns clear. No preliminary medication need be used in children under nine years of age. Adults may be given by the rectum one hour before the operation 0.3 to 1.3 Gm. (5 to 20 grains) of chloretone in a suppository, or dissolved in 8 to 15 c.c. (2 to 4 drams) of ether and the same amount of olive oil. Or paraldehyde, 8 to 15 c.c. (2 to 4 drams), dissolved in equal amounts of ether and olive oil may be used instead. Or isopral, the rectal dose of which is 1.3 Gm. (20 grains), may be given as a substitute for paraldehyde. This rectal medication is followed in fifteen minutes by 0.008 to 0.015 Gm. (⅛ to ¼ grain) of morphin with 0.0006 Gm. ($\frac{1}{100}$ grain) of atropin injected hypodermatically. For alcoholics, it is recommended that a hypodermic injection of 0.0006 Gm. ($\frac{1}{100}$ grain) of hyoscin hydrobromide be given two hours before the ether, and the same dose repeated along with 0.015 Gm. (¼ grain) of morphin. Scopolamin 0.0005 to 0.0006 Gm. ($\frac{1}{120}$ to $\frac{1}{100}$ Gm.) and 0.01 to 0.015 Gm. (⅙ to ¼ grain) of morphin may be given one hour before operation instead of the morphin and hyoscin. This preliminary narcotic medication is perhaps no more necessary than in pulmonary anesthesia, and perfectly satisfactory results are obtained without it. When these drugs are employed, about 25 per cent. less of the ether-oil mixture may be used than is required without them.

The technic of the anesthesia is simple. The apparatus should be sterilized. The ether is administered twenty or twenty-five minutes before the time of operation. It is best given with the patient in the lateral pelvic position, although the dorsal position may be used. The catheter is lubricated and passed into the rectum about 10 cm. (4 inches). For a large adult, a mixture of 60 c.c. (2 ounces) of olive oil and 180 c.c. (6 ounces) of ether is used. This 75 per cent. mixture is slowly poured in the funnel. It should be allowed to flow very slowly. About one minute should be allowed for each 30 c.c. (1 ounce). The patient should be kept perfectly quiet. Conversation should not be engaged in. After about 150 c.c. (5 ounces) have been administered the patient will be unconscious.

For every 9 kilos (20 pounds) of body weight 30 c.c. (1 ounce) of the 75 per cent. mixture may be given. In the case of children, a mixture containing 50 to 65 per cent. of ether is sufficient. Not more than 240 c.c. (8 ounces) should be given to any adult, no matter how heavy. If the anesthesia according to this ratio is not adequate, it is better to supplement it with a little inhalation narcosis. Children under five years of age require a little more ether than is indicated by this ratio, but, as absorption is more rapid than in the adult, how much they need can be observed as the fluid slowly flows in. If the patient goes to sleep before the full amount has been given it should be stopped.

In from ten to thirty minutes the patient is unconscious. The breathing should be regular, the reflexes should still be active, the voluntary muscles should be relaxed, and the patient should be ready for operation. If breathing becomes labored, the reflexes abolished, or cyanosis appears, 50 or 100 c.c. of the mixture should be withdrawn and the bowel irrigated with water until the patient's condition is satisfactory. Cyanosis due to falling back of the tongue is to be met the same as in pulmonary anesthetization. If the patient is not under deeply enough, a folded towel placed over the nose and mouth will cause more rebreathing of the expired ether. There is no objection to adding a little extra ether by inhalation from the open mask if necessary.

At the end of the operation the bowel should be washed out with water not warmer than body temperature, through a double tube or by means of two tubes—one for inflow and one for outflow. This washing out of the bowel should employ 4 to 6 liters (1 to 2 gallons) of warm soapy water. When this washing is completed, the last of the water should be allowed to run out, the outflow tube should be removed or closed, then 60 to 120 c.c. (2 to 4 ounces) of olive oil should be introduced, and followed by 500 c.c. or 1000 c.c. (1 or 2 pints) of water, and the tube withdrawn. This oil and water should be retained in the bowel. In ten or fifteen minutes the patient should regain consciousness. Analgesia should continue for some time after the patient awakes. In the majority of cases there should be no nausea, vomiting, nor the malaise which characterizes pulmonary anesthetization.

It is possible to keep the patient anesthetized for a long time by introducing first about 120 c.c. (4 ounces) of the mixture and later the rest of the allowance, supplemented, if necessary, by ether or a very few drops of chloroform by inhalation. Experience has showed that 240 c.c. (8 ounces) of a 75 per cent. mixture is capable of keeping a patient weighing 75 kilos (165 pounds) anesthetized for three hours, without supplemental anesthetic.

Bloody stools, abdominal pain, or colitis have not followed this method. No deaths or untoward results are reported. We are in the habit of giving the anesthetic to the patient in his bed. Women have been anesthetized, operated upon, returned to bed, and recovered from their anesthetic without knowing that an operation had been done. All complications seem to be less than in ether by other methods. Patients who have taken ether by inhalation and by oil enema quite invariably are enthusiastically in favor of the latter.

This method seems of special value in cases in which the element of fear is a factor for here it meets the requirements for overcoming anoci-association. In children, in cases of disease about the air ways, and in alcoholics, it is of advantage. It seems especially effective in the obese. In bronchoscopy and esophagoscopy it is most valuable.

It is contraindicated in cases with disease of the bowel such as colitis, hemorrhoids, and anal fistula. If the beginning of the injection causes pain, it

should be discontinued. Emergency cases in which time for emptying the bowel can not be taken are not adapted to this method.

It is possible for the operator himself, under circumstances of emergency, to administer the anesthetic. When this is done it is best to use a 55 to 65 per cent. solution of ether in oil, and allow fifteen or twenty minutes for the ether to take effect.

European surgeons have preferred to use a weaker solution of ether. Equal parts of ether and olive oil are used successfully. With a mixture of this proportion, the patient may be given 1 c.c. of each for every ½ kilo (1 pound). A patient weighing 75 kilos would receive 150 c.c. each of ether and olive oil. In order to control the fluid, a bottle having

FIG. 67.—APPARATUS FOR RECTAL ANESTHESIA WITH OIL AND ETHER.
The catheter is passed into the rectum and the bottle inverted.

two glass tubes of different lengths may be used. The shorter tube is connected with a rubber tube which is connected to a small catheter. To start the anesthesia the bottle is reversed and the fluid flows into the rectum. The catheter is left lying in the rectum. By lowering the bottle the fluid flows out of the rectum back into the bottle. This may be done when the narcosis seems too deep. By keeping the bottle a little higher than the rectum, the fluid stays in the rectum but if the bowel becomes overdistended with gas the latter escapes through the bottle (Fig. 67).

Ether vapor rectal anesthesia has been quite supplanted by the oil-ether mixture. It was used formerly by vaporizing ether by placing the bottle in a water bath at a temperature of 43°C. (110°F.) and conducting the vapor to the rectum by a rubber tube. Oxygen was combined with it to allay irritation. Much skill was required; and bloody stools followed in a large proportion of cases.

Intravenous ether anesthetization is another of the little used methods. A 5 per cent. solution of ether in normal salt solution (Ringer) is employed. This is injected slowly into a vein. From 500 to 4000 c.c. (1 to 8 pints) of this solution are used for an ordinary operation. The solution is made by mixing the ether cold and then warming it in a water bath to 38°C. (100.4°F.)

(Kümmell). The warming process drives off about 1½ per cent. of the ether, so that a 3.5 per cent. solution is infused.

It is well to precede the ether by an injection of 0.0005 Gm. (1/120 grain) of scopolamin and 0.01 Gm. (1/6 grain) of morphin. The median basilic vein is exposed and a canula introduced as for saline infusion. Ether solution and saline solution are connected by a Y-tube, so that one or the other may be flowing all the time. The ether solution first flows to give a satisfactory anesthesia, and then pure normal salt solution is allowed to flow. By alternating the two the degree of anesthesia can be accurately controlled.

By using much water the advantages of saline infusion are secured, and patients may be expected to go through operations and come out without depression. A large proportion of the cases upon which this method has been employed by the inexperienced have developed thrombosis or embolism. Burkardt and Kümmell have had good results. Except in experienced hands it is not to be considered as a routine practice. It may be used in patients who need more fluids and especially for operations about the face and air way. It is contraindicated in the plethoric and in patients with arteriosclerosis. The ether is rapidly excreted into the air through the lungs.

Anesthesia is produced in about ten minutes—in feeble patients, in five minutes—by which time 100 to 300 c.c. of solution, containing 4 to 5 c.c. of ether, have been injected. Operations lasting over two hours have been done by this method. Kümmell regarded it as the ideal anesthesia for many conditions. W. F. Honan and J. W. Hassler (Annals of Surg., vol. 58, 1913) who studied this method thoroughly and perfected an apparatus for its use, saw a distinct field for its employment. (For technic, see Intravenous General Anesthesia, page 164.)

Intramuscular injections of ether have been used and have produced general anesthesia. The injections have been made in the gluteal muscles in amounts of 30 to 80 c.c. (1 to 2½ ounces), usually 60 to 70 c.c. (2 to 2⅓ ounces). The anesthesia in many cases has been unsatisfactory. Pain has persisted afterward. Hematuria and other complications are reported. The method is to be condemned as a routine practice.

The after-effects of ether are unpleasant. Nausea follows the inhalation method and is common with the other methods. Vomiting is present in a large proportion of cases unless the stomach has been washed out after the administration is discontinued. Even after skillful administration by the open drop method, nausea and vomiting are present in 30 to 40 per cent. of cases. There is always a certain amount of depression. The blood cells suffer positive damage. Even after a short anesthesia, anemia occurs. Following prolonged anesthesia with ether, there is an anemia from which the patient does not begin to recover for several days, and the activity of the leukocytes is impaired. Thus it is seen that ether, besides irritating the kidneys and respiratory organs, and producing depression of the vital centres, damages the resistance of the body against infection at a time when resistance is most needed.

Conclusions Concerning Ether Inhalation by the Open Drop Method.—This is the safest and simplest general anesthesia. It is not as agreeable to take as chloroform, but much more agreeable than by the closed method. If there is aversion to it, the nitrous oxide and ether sequence is to be recommended in its stead. In expert hands it can be made quite free from disagreeable features. It gives complete relaxation and anesthesia. It is not highly toxic, and has a wide margin of safety between the dosage required for anesthesia and the toxic dose. Control of the anesthetic is good. It causes some post-operative damage to the blood and viscera but not so

much as chloroform. It is the safest, simplest, and most satisfactory method of general anesthesia if given by an expert; and it should be the method adopted for general use.

CHLOROFORM

Chloroform ($CHCl_3$), employed in surgery, is a colorless, sweet-smelling liquid. It is produced in the pure state by several manufacturers. It boils at 65°C. (149°F). It is non-inflammable; but its vapor is decomposed by heat. If it is used near a flame, poisonous and irritating gases are evolved. It is a cardiac depressant. Its high boiling point and lesser diffusibility render it more stable than ether. It produces practically no respiratory irritation. It is not eliminated so readily from the blood on account of its lesser diffusibility; and it has the danger of accumulative effect. Its anesthetic strength is about seven times greater than ether. Its administration requires more skill and watchfulness than ether. Two percent. chloroform vapor, or less, with air is sufficient to produce anesthesia. Its administration may be combined to advantage with oxygen by means of the vaporizing bottle (Fig. 64).

Chloroform is commonly given by the most open method possible. A mask is used, covered with a few layers of gauze, sufficiently thick to prevent broken drops of chloroform from spattering through (Fig. 61). Upon this the drug is dropped at short range, or a folded piece of cloth may be held near the face as an inhaler. For an adult about 2 c.c. (30 minims) a minute are required at first; when anesthesia is established about 1 c.c. (15 minims) a minute suffices. An old rule is, "One drop for every inhalation." Chloroform takes hold of patients more profoundly. They go under with less effort. The breathing is more quiet. The face instead of being injected is pale. The pulse instead of being full and strong is slightly weaker than normal. But by carefully watching the patient and keeping him just beyond the stage of awakening, using the minimum of chloroform, the anesthetic progresses quietly and safely. *The danger of chloroform is that it is possible for a healthy person to inhale a poisonous dose in a single breath.* This does not occur with ether. Most of the deaths from chloroform have been in healthy people at the beginning of its administration. During the stage of excitement, if much chloroform is poured on the mask just at the beginning of inhalation, death may result from cardiac or respiratory paralysis. For this reason it is important, when the patient takes a deep breath, to remove the inhaler. This must be watched for constantly, and especially when the sphincter of the anus is dilated or other respiratory-exciting nerves stimulated. There is less nausea and vomiting with chloroform than with ether, but more actual shock from the anesthetic. It produces degenerative changes in the liver and other glands, which may prove fatal several days after the operation.

The treatment of **chloroform accidents** should begin with prompt discontinuance of the anesthetic and the admission of fresh air in motion. If the heart has stopped, pressure on that organ should be made through the chest wall while artificial respiration is practised. If no return of heart pulsations is secured, pressure on the chest and under the border of the left costal arch should be made to empty the dilated heart. Artificial respiration or tracheal insufflation should be continued. Then 300 to 500 c.c. (10 to 15 ounces) of normal salt solution, containing 1 per cent. of glucose, should be injected into a vein. Pressure on the heart should again be made. If the heart action is not restored by this treatment, the abdomen

should be opened below the left costal arch, and the heart compressed rhythmically against the chest wall by the hand pressing upon the diaphragm.

It has been shown that chloroform is especially attracted by the suprarenal capsules. The secretion of epinephrin is inhibited by actual organic changes affected in the capsules by chloroform. Many cases of death following chloroform narcosis, attributed to embolism or status lymphaticus, are, perhaps, due to adrenal insufficiency. Delbet (Trans. Acad. de Med. de Paris, 1912) injected 0.4 mg. ($\frac{1}{150}$ grain) in ordinary chloroform narcosis at the beginning of the operation. In operations with much traumatism 0.6 mg. ($\frac{1}{100}$ grain) is given. The dose may be repeated several hours after the operation if operative shock is present.

Conclusions Concerning Chloroform Inhalation by the Open-drop Method.—It is a most dangerous anesthetic. The margin between the toxic dose and the dose necessary for anesthesia is too narrow for safety. It is most agreeable to take because of its non-irritating character. It gives complete anesthetization and relaxation. The after-effects on the blood and viscera are so serious that fatal results, long after the operation, may supervene. It should not be regarded as an anesthetic for routine operative use, but reserved especially for outdoor surgery, and that especially in warm climates.

NITROUS OXID GAS

Nitrous oxid gas (laughing gas, N_2O) is produced by slowly heating ammonium nitrate which breaks up into water and nitrous oxide. It is a colorless gas with a sweetish taste. When inhaled it produces narcosis. On account of the great volatility of the agent the patient quickly goes under, quickly comes out, and it is quickly eliminated from the blood. It is inhaled through a tight-fitting mask, the gas first being turned into a rubber bag. For short anesthesia, it is quite free from danger if carefully given. When carried to full anesthesia, it has the disadvantage of producing a deep cyanosis due to its exclusion of oxygen from the lungs and red blood-cells. It may be used for short operations, but is best used with oxygen in all cases. A prolonged anesthesia may be conducted if it is combined with oxygen. As nitrous oxid is used but little in the pure state, its further discussion will be found under Nitrous Oxid and Oxygen Combinations, page 120.

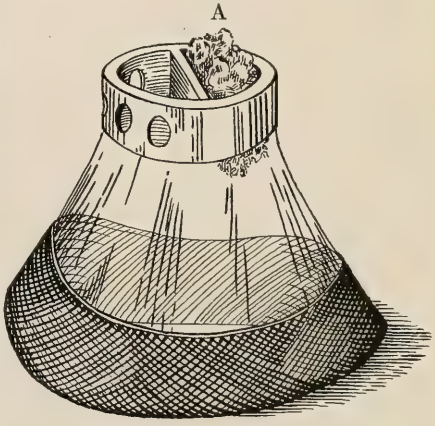


FIG. 68.—ETHYL CHLORID INHALER.
The ethyl chlorid is given by the drop method upon the gauze in the opening *A*.

ETHYL CHLORID

Ethyl chlorid (C_2H_5Cl, kelen, antidolorin) is a gas at ordinary temperature; when compressed it becomes a colorless liquid. It boils at 15°C. (59°F.). It is put up in glass tubes, from which it is liberated by opening a small vent in one end, the heat of the hand causing the gas and liquid to be forced out. It is highly inflammable. Being very volatile, an evanescent anesthesia, from which the patient quickly comes out, may be maintained by its inhalation. It may be given in an ether mask, but the gas must be somewhat more confined than with ether. This is done by nearly closing

the end of the mask. It is best given through an inhaler with a close-fitting attachment (Fig. 68). Three to 5 c.c. of the agent will give anesthesia for a minute. When used in a bag the contents of a 5-c.c. tube may be emptied in the bag at once. It is best used from the tube having a capillary opening which delivers a small stream. It produces little throat irritation. It is employed for short anesthesias and as a preliminary to ether. It is used also in combination with nitrous oxid, ether and chloroform. It is perhaps as safe as chloroform or ether. Its great volatility causes the patient to come out promptly as soon as the anesthetic is discontinued (see Mixed Anesthesia below).

ETHYL BROMID

Ethyl bromid (C_2H_5Br. hydrobromic ether, bromethyl) is a colorless, very volatile liquid. It decomposes in the light and rapidly volatilizes in the air. Its anesthetic action is similar to that of ethyl chlorid. It is given in a closed ether inhaler. Narcosis is produced by 10 to 30 c.c. (⅓ to 1 ounce) which comes on in one or two minutes and lasts two or three minutes. It should not be confused with ethylene bromid which is poisonous and dangerous.

BROMOFORM

Bromoform is a heavy liquid having an odor and action similar to chloroform but is much less satisfactory.

AMYLENE

Amylene (pental, C_5H_{10}) is a colorless, oily, inflammable liquid, which has properties similar to chloroform. As an anesthetic it is unsatisfactory and dangerous.

SOMNOFORM

Somnoform is another of the anesthetics, used like ethyl chloride, and which up to the present time has not proved to be altogether satisfactory.

ACETAL

Acetal (dimethylacetal) is an anesthetic similar in action to chloroform. Two parts of acetal and 1 part of chloroform mixed have less depressing effect upon the heart than chloroform alone.

OTHER ANESTHETICS

Other anesthetics are *methyl ether, methylene bichloride, methylene ether, methylal.* These are but little used.

MIXED ANESTHESIA

Mixed anesthesia is of two kinds: following one anesthetic with another in sequence, and mixtures made up of two or more anesthetics. Mixed anesthesia aims to overcome the objections inherent in the various anesthetic agents when used alone. This method generally requires more skill and pains and is used largely by expert anesthetists.

Anesthetic Sequences.—One of the most used is the *gas-ether sequence.* In this the anesthetic is begun with nitrous oxides and oxygen and continued with ether. It can be accomplished with the simple gas bag inhaler, followed by the simple ether inhaler; but better than this is the use of the compound apparatus in which ether can be started while the gas is still being given.

This anesthesia avoids the unpleasant first stages of ether, characterized by coughing and struggling, if hastily given; or, if these are avoided, by the consumption of much time. The patient goes under in a few seconds with the gas; the ether is then begun, and deep anesthesia is secured in three or four minutes. Much less ether is required, and nausea and vomiting diminished.

The *chloroform-ether sequence* is used also to overcome the objections of the first stages of ether. Unfortunately the greatest hazard with chloroform is at the beginning of the anesthetic when the patient may struggle and take a deep breath. For this reason this combination must be used with care. It is of use with alcoholics and certain plethoric men, with persons who have had an unpleasant experience with ether, with nervous women, and with children. But in the hands of a skillful anesthetist with an open inhaler ether alone can be given as satisfactorily.

The *ethyl chlorid-ether sequence* is of use in some cases. It possesses much of the advantage of the nitrous oxide-ether sequence and requires less apparatus. If can be applied to the ordinary ether inhaler. The open or closed method may be used. The ethyl chlorid should be dropped on, not sprayed. From 3 to 8 c.c. are used. The patient passes under pleasantly. After 5 c.c. have been dropped on the mask, the ether is begun.

Anesthetic Mixtures.—These are made with the view of adding the quicker anesthetizing power of chloroform to ether in order to diminish the amount of ether required and at the same time reduce the dangers of chloroform. Most of them accomplish this in but a slight degree. The *Vienna mixture* (ether 6, chloroform 1), *Post's mixture* (equal parts of alcohol, chloroform and ether), *Billroth's mixture* (ether 1, alcohol 1, chloroform 3), A.C.E. *mixture* (alcohol 1, chloroform 2, ether 3), and C.E. *mixtures* (chloroform 1, ether 2; and C.E. mixture, chloroform 1, ether 4) have all found favor in the hands of some surgeons. These combinations are somewhat closer than mixtures, and possess the merit of having a boiling point higher than that of ether and lower than chloroform. Thus, 119.5 Gm. of chloroform and 74 Gm. of sulphuric ether (by volume, 43.25 and 56.75) combine into a molecular union which contains neither free ether or chloroform, and has a boiling point of 52°C. (125.6°F.) This is an excellent anesthetic.

British surgeons have made large use of a mixture of ether, 16 parts, and chloroform, 1 part. This seems to be less irritating than pure ether and gives a better sustained anesthesia.

Schleich endeavored to find an anesthetic agent having a boiling point the same as the internal temperature of the body so that the amount eliminated by each expiration would be about the same as that absorbed by inhalation. The higher the boiling point of an anesthetic the slower is it eliminated from the system. *Schleich's mixture*, made in three different strengths, is composed of chloroform, ether, and petrolic ether (benzin). This possesses many advantages, but the benzin is an inert material. Meyer and Weidig replaced the benzin by ethyl chlorid and produced an anesthetic which is called *anesthol*. This consists of the molecular combination of chloroform and ether, 83 per cent. by volume, plus 17 per cent. ethyl chlorid; or chloroform 35.89 per cent. ether 47.10 per cent. and ethyl chlorid 17 per cent. by volume. Anesthol has a specific gravity about the same as the human blood and boils at about the internal temperature of the human body. It is best administered by the drop method with the double frame open mask; 8 or 10 Gm. are required to put the patient under, and after that it may be given at the rate of about 1 Gm. a minute, drop by drop, the same as chloroform. The patients go under easily and come out easily with little nausea or vomiting. It com-

bines the advantages of ether and chloroform, being less disagreeable than the former and less dangerous than the latter.

Conclusions Concerning Anesthetic Mixtures and Sequences.—Most of these combinations of anesthetics have had their day, and should now disappear. Those that are worthy of consideration are the use of nitrous oxide before ether, nitrous oxide during some painful step in combination with local anesthesia, and morphin followed by ether in the case of nervous patients.

Anesthetics Combined with Oxygen.—One of the dangers of anesthetic vapors and gases is that their action consists in taking much of the room in the lungs normally occupied by air and in decreasing the oxygen in the red blood cells. This is the reason for the cyanosis in ether and nitrous oxide narcosis. If instead of depending for his oxygen upon the air which he can get, the patient is given pure oxygen artificially, a large element of the danger and disadvantage of the general anesthetic is obviated. One of the most important advancements in anesthesia has been the employment of oxygen to this end. It reduces the danger of all anesthetics without diminishing their anesthetic value.

Ether and oxygen are given in combination by using the mask and rubber bag inhaler and permitting the patient to have about 3 parts oxygen and 1 part air with the ether vapor, which may be done by mixing the two or by removing the mask at every third inhalation and letting the patient breathe air. Or the oxygen may be run through the liquid ether in the Junker inhaler; or oxygen may be conveyed by a rubber tube into the ordinary ether mask. The simplest way is to allow the oxygen to flow through an ether bottle into the ordinary mask, ether being also poured into the mask as needed (about ½ dram of ether every five minutes suffices). If both the oxygen and ether are warmed we have an anesthetic which is practically without hazard, and much more agreeable than ether alone.

Chloroform and oxygen are well given by the method of allowing the oxygen to bubble through the liquid chloroform carrying the vapor with it. This may be conveyed into the simple cloth-covered chloroform mask; or, in the hands of the expert, the closed mask may be used. The value of this combination is still increased by using warmed anesthetic.

Nitrous oxid and oxygen is the most advantageous combination of all, and may be used for prolonged anesthesia. Both of these gases were discovered by Joseph Priestley in 1774; they were first employed together as an anesthetic combination by E. Andrews of Chicago in 1868. In America they are employed in proportions of about 6 or 8 per cent. of oxygen and 94 or 92 per cent. of nitrous oxid; although in Germany 10 to 20 per cent. oxygen is used. They are given with the closed inhaler having two bags, one for each gas, which is admitted from its separate tank (Fig. 69). A certain amount of air should be given in prolonged anesthesia; this may be done by using an air-oxygen mixture (air 1, oxygen 2), or by allowing an inhalation of air every four or five inspirations.

If these gases are warmed by interposing a heated tube between the bag and the mask so that they are inhaled at the temperature of the lungs, 38°C. (100°F.) an anesthetic is secured which may be designated as the safest and most agreeable known.

The mixture must be adjusted with precision to the needs of the individual patient. A patient who is doing well with 9 per cent. of oxygen will develop cyanosis when the oxygen is reduced to 7 per cent.; and when it is raised to 11 per cent. he will show excitement and other signs of inadequate narcosis. The most satisfactory anesthesia is secured with 6 or 7 per cent. of oxygen. It requires about 11 per cent. of oxygen completely

to eliminate the cyanosis of nitrous oxid. Using air for the purpose of getting oxygen fails because 79 per cent. of air is nitrogen and in order to get enough oxygen to be of use so much nitrogen must be taken that the amount of nitrous oxygen is reduced below the amount necessary for narcosis. The weakest amount of nitrous oxid that will produce narcosis is 70 per cent.

This combination is the least depressing of any anesthetic. It can be used in the aged and the young, although it is not adapted to infants. Patients with pulmonary tuberculosis take it better than any other anesthetic. The blood is not damaged as by ether. It is followed by the least shock, and patients recover most promptly and with the least damage. It does not act well in prolonged operations upon persons who have used much alcohol or tobacco. In marked arteriosclerosis, emphysema, asthma, and obstructions of the respiratory tract it does not act well. In cases of high blood-pressure, pronounced valvular diseases with dilated heart, regurgitant aortic lesions, and apoplexy, it is contraindicated because it causes marked rise of blood-pressure.

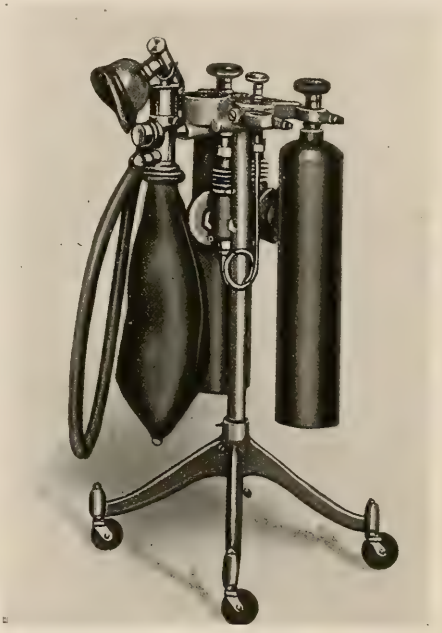


FIG. 69.—NITROUS OXID AND OXYGEN APPARATUS.

A chief objection to this anesthetic is that it can be administered only by a skilled anesthetist who has especial experience in its use. Patients come out quickly and go under quickly, and, therefore, the closest attention of the anesthetist is required every moment. Apparatus of a rather complicated character must be used. Another objection to this anesthetic is the cost. About $5.00 an hour is the average expense for the gas. By using the rebreathing method of Gatch the cost may be reduced to $1.50 per hour (see Nitrous Oxid and Carbon Dioxid Mixture, page 123). Some hospitals have installed a plant for the making of nitrous oxid gas, and carry it to the operating room by pipes.

Nitrous oxid anesthesia does not give the muscular relaxation which is obtained with other anesthetics; hence it does not serve well in abdominal and rectal operations in which relaxation is desirable. Skilled anesthetists can secure relaxation for a time by pressing the anesthesia, but a little ether is often found necessary. Because of the venous congestion, it is not satisfactory for major operations on the mouth, nose, and air passages. Nitrous oxid causes increase of pulse rate. Under light narcosis it may be 140 or 160 per minute. It is strong and full, and becomes slower when ether is added.

In dark-skinned races it is difficult to use it because of the fact that the color of the skin, the index of cyanosis, can not be of much service. Only the experienced anesthetist who is familiar with the respiratory behavior can give nitrous oxid to a negro.

The apparatus devised by Hewitt has been much improved by Teter, Gatch, Cunningham, Gwathmey, and Woolsey. The gas from compression tanks is admitted to a mixer in the desired proportions. Thence it passes to a rubber bag; and from there to the mask. The mask is constructed so as to fit the face snugly. A manometer attachment shows the pressure under which the gas is entering the lungs. By having a tight-fitting mask this pressure can be raised to 5 mm. of mercury at which pressure the anesthesia can be deepened at will so that ether does not become necessary. There is a chamber for heating the gas. All modern apparatus is provided with an ether chamber placed on the mask or between the mask and the bag so that ether may be administered when desired.

The bag is first filled with nitrous oxide up to the point of distention so as to give some pressure, and the mask placed on the patient's face. No oxygen, or but very little, is allowed with the first few inhalations. A valve is then opened and the gas allowed to flow from the bag to the mask. As the gas in the bag is used and the patient becomes dusky, oxygen is admitted from the tank. After this the desired mixture is maintained. A skillful anesthetist does not confine himself to any particular mixture, but judges by the condition of the patient, and admits enough oxygen to overcome the cyanosis, increasing the one or the other as the requirements indicate. After from two to six breaths of pure nitrous oxid, rebreathing of a small part of the exhaled gases is allowed (see Nitrous Oxid and Carbon Dioxid Mixture, below). Anesthesia is produced in one or two minutes. It may be known that anesthesia has been produced by the quiet breathing of the patient, relaxation of the arms, loss of conjunctival reflex, and fixation or slight oscillation of the eyeballs. Muscular rigidity persists in alcoholics.

For *endotracheal insufflation* with this mixture, it is not necessary to use the bag. The gas may be conducted directly through the tracheal catheter. A mercurial manometer, which automatically blows off at about 25 mm. of mercury pressure, is of advantage.

The same apparatus without the bag is employed when nasal tubes are used. By this means patients may be anesthetized for operations about the mouth and face. They may be allowed to come out and answer questions when desired. Dentists successfully employ a nose piece and no gas bag. With this simple apparatus regulated by a valve to adjust the amount of each gas admitted, light or deep anesthesia may be produced most effectively.

Conclusions Concerning Nitrous Oxid and Oxygen Anesthesia.—For short anesthesia for such operations as drilling or pulling teeth, incising abscesses and dressing painful wounds, it is the safest anesthetic used. For prolonged anesthesia, twenty minutes or more, it is more dangerous than ether. It is the most agreeable of inhalation anesthetics, and is easily controlled. It is not an efficient anesthetic, as in many cases it produces neither relaxation nor complete analgesia. Its after-effects are very slight, and for this reason it may be used freely and without fear of later unpleasant results. It is not so convenient to administer as ether, and requires more apparatus and more expert knowledge. It should be regarded as the anesthetic of choice for short anesthesia.

Anesthetics Combined with Carbon Dioxid. (Rebreathing).—In all pulmonary anesthesia there is a certain degree of carbon dioxide employment. The rebreathing of carbon dioxide is a factor in all. With ether and chloroform, rebreathing of exhaled gases is objectionable and often dangerous, and should be practised only by the skilled anesthetist

or when the conserving of the anesthetic is imperative. It is accomplished by using the closed mask, and excluding a certain amount of air. The dangers of rebreathing are (1) the exclusion of oxygen (anoxemia), and (2) overconcentration of the anesthetic vapor. Organic substances in the expired air and carbon dioxide are harmless.

Carbon dioxid is a powerful respiratory stimulant and may be used to mitigate the harm of respiratory depressants. An excess of carbon dioxid in the blood (hypercapnia) during anesthesia is of advantage. It is promptly recovered from. An amount of this gas not exceeding 22 per cent. when inhaled increases blood-pressure and stimulates respiration. An amount over this causes blood-pressure to fall. It is also known that too little carbon dioxid in the blood (acapnia) is depressing and conduces to shock, the respirations become feeble and the movement of the blood stream slow. When rebreathing is employed in connection with anesthesia greater vigilance and skill are required.

Nitrous oxid and carbon dioxid were utilized by W. D. Gatch in a most effective way to reduce the amount of nitrous oxid required to produce a given degree of anesthesia. The mask and its connection with the gas bag are arranged so that the inspired gas is breathed back into the bag and rebreathed, or by sliding a valve, the patient inhales only from the bag and exhales only into the outside air. Gatch admits the two gases to a box attached between the bag and the cone. Ether may be admitted to this box by the drop method. The bag is filled with nitrous oxid with a very little oxygen. The patient inhales this mixture and breathes it out into the free air, thus filling the lungs with the nitrous oxid and oxygen. The bag is then filled with nitrous oxid and oxygen, and the patient made to rebreathe this, exhaling not into the free air but into the bag, and inhaling only from the bag. The patient rebreathes thus for from five to eight minutes. Then the valve is moved and exhalations escape into the outside air till the bag is emptied. The bag is again filled and the same procedure repeated. Anesthesia continued in this manner uses about one-fourth as much nitrous oxid as by the usual method in which rebreathing is not employed.

Ether may be added at any time. By dropping ether at the rate of 120 drops per minute for not more than two minutes at a time the ether concentration is kept below 7 per cent.

This method of rebreathing gives a slower pulse rate because of the better tone of the cardiovascular system under the influence of a moderate amount of carbon dioxid. Another important factor is that, by rebreathing, the body heat is not lost; and it will be observed that the temperature of the body remains higher. Skill is required to adjust the rebreathing to hold the patient between the two dangerous extremes of excess of oxygen and deficiency of carbon dioxid.

HYPODERMIC NARCOTIC AGENTS

Morphin is the most useful narcotic for hypodermic use. It is of decided value in the case of alcoholics or athletes to precede ether or chloroform. An injection of 0.015 Gm. (¼ grain) twenty minutes or half an hour before the anesthetic mollifies the stage of excitement and materially reduces the amount of anesthetic required. If the operation is to be prolonged this may be divided into two injections.

Nervous adults may be given an injection of morphin with advantage twenty or thirty minutes before the anesthetic. By giving to an adult an injection of 0.008 Gm. (⅛ grain) of morphin two hours before an opera-

tion and 0.01 or 0.015 Gm. ($\frac{1}{6}$ or $\frac{1}{4}$ grain) half an hour before operation, a very few drops of chloroform inhaled will render the patient insensible to pain. It is possible with this morphin-chloroform narcosis to have analgesia without abolishing the reflexes, the patient also being able to hear and answer questions and move his muscles at will.

Scopolamin is a sedative used to supplement morphin. It is given in doses of 0.00025 to 0.001 Gm. ($\frac{1}{240}$ to $\frac{1}{60}$ grain), usually 0.0004 to 0.0006 Gm. ($\frac{1}{150}$ to $\frac{1}{100}$ grain). A hypodermic injection of this drug one hour before operation and morphin half an hour before operation brings the patient to the table in a semidrowsy state with the psychic paths of shock closed. It is, therefore, highly desirable for nervous patients. The numbing of sensations with these two drugs in many patients is so profound that operations may be done without any further anesthesia. If an anesthetic is required but a little is needed. Hyoscyamin is used the same as scopolamin. The scopolamin and morphin may be given together an hour before operation and repeated half an hour before operation, with the result in many cases that further anesthetic may be dispensed with. From the standpoint of safety this is one of the dangerous anesthetics.

This combination of morphin and scopolamin is the combination employed in inducing "twilight sleep." Many drugs have been substituted for the scopolamin. They have all proved to be dangerous. Many deaths have followed the use of this method of anesthesia. The pseudoscientific enthusiasm for this method in child-birth which was fostered by deluded women and exploited by the press has been productive of great harm.

Conclusions Concerning Morphin and Scopolamin Injections.—This is the most dangerous of anesthetic methods, and has been responsible for a larger proportion of deaths than any other method of anesthesia. Surgery never accepted it as an adequate anesthesia; and on account of its danger it should not be used alone. It is simple and easily given, but to secure anesthesia it must be followed by a general anesthetic in a large proportion of cases. Its only recognized field of usefulness is as a preliminary to other general anesthetics, and here it should be very restricted because it masks and confuses the signs if it does nothing worse.

ANESTHESIA BY THE PHARYNX

In operations about the nose and mouth it is often desirable to convey the anesthetic directly back to the larynx so that apparatus over the nose and mouth may be dispensed with and so that the nose or mouth may be tamponed to prevent the respiration of blood. This is done by first cocainizing the nose and pharynx; the patient is then anesthetized with a general anesthetic; the largest possible rubber tubes are then lubricated and one passed into each nostril and back in the pharynx as far as a level with the epiglottis, the tongue being drawn forward and depressed so that the ends of the tubes may be located by sight and feeling with the finger; a silk thread is tied about each one at the anterior nares and the tubes are allowed to continue beyond this so that they may end over the forehead, chest, or at the side of the head, and are connected with the anesthetic inhaler. With the tongue pulled forward the pharynx is then carefully packed with dry gauze in such a way that an air space is left between the ends of the tubes and the glottis. This packing may be brought as far forward as is desired. Or the curved glass nasal tubes may be used (Figs. 64 and 65). The patient breathes through the tubes. The anesthetic may be given through an ordinary inhaler, or the principle of the Junker inhaler may be employed. I have devised a simple funnel inhaler for this use which is adapted to chloroform, ether or ethyl

chloride (Fig. 66). A small pump or bellows may be used to keep a current of ether vapor flowing through the tubes.

Conclusions Concerning Intrapharyngeal Anesthesia.—Ether given by this method may be as safe as by the open drop method. Special experience and skill are required. This method, excepting where differential pulmonary pressure is required, is quite as useful as intratracheal insufflation and much less difficult and hazardous. It should be regarded as the best means of anesthesia in cases in which the face mask would interfere with an operation.

ANESTHESIA BY THE LARYNX

Laryngeal puncture has been employed by French surgeons with decided satisfaction in special cases. A fine canula is inserted through the anterior tissues of the neck in the middle line, and through the crico-thyroid membrane. By means of this canula anesthetic vapor is pumped into the larynx. Only exceptional cases justify this method.

ANESTHESIA THROUGH THE TRACHEA

In operations about the mouth and throat, in which tracheotomy is done, a trachea tube is inserted and the anesthetic given directly at the tube through an ordinary inhaler. In order to remove the apparatus farther away from the field of operation a rubber tube may be conducted from the trachea tube to the cone. *Intratracheal insufflation* may be applied without the tracheotomy.

Intratracheal Anesthesia.—This method of anesthesia is applied in cases in which intratracheal insufflation of the lungs is indicated in thoracic surgery. It may also be used with advantage in cases in which respiratory paralysis may occur, in cases in which the disease causes obstruction of the air way, in cases in which the position of the patient obstructs breathing, in cases in which it is desirable to have the apparatus of anesthesia out of the way of the surgeon, in cases in which it is necessary to tampon the pharynx to prevent blood or other fluids running into the larynx, in cases in which it is important that the movements of respiration should be steady and shallow, and in cases of plethoric or cyanotic patients who develop congestion of the throat and take ordinary pulmonary anesthetics badly.

In a certain number of cases it will be found difficult or impossible to establish relaxing anesthesia unless 0.01 to 0.015 Gm. ($\frac{1}{6}$ to $\frac{1}{4}$ grain) of morphin is given as a preliminary. With morphin the method is effective in all cases.

The patient must first be anesthetized in the ordinary manner, and placed on the table in position for operation. If the patient has not been well anesthetized a troublesome cough will follow the introduction of the tube into the trachea. The head should be thrown back to straighten the upper air way. A long catheter is introduced through the mouth into the trachea. Force should not be used. It should slide gently. This catheter should not be too large, but should fit so loosely as to leave a space between it and the wall of the trachea through which the insufflated air may escape from the lungs. The catheter should be firm but elastic. The silk woven variety or a new pure rubber catheter is best. It is preferable that the opening be at the end of the tube rather than the side. The diameter of the catheter need not be more than 8 mm. ($\frac{5}{16}$ inch) and the lumen 4 mm. It should be at least 36 cm. (14 inches) long. For an adult a No. 22 or 24 French scale catheter may be used. This is best introduced under the guidance of vision with the aid of the laryngoscope. The tip of the catheter should lie 3 or 4 cm. ($1\frac{1}{2}$ inches) above the bifurcation of the trachea.

The catheter should have been sterilized and the mouth sponged clear of mucus and saliva before its introduction. Care should be taken that the catheter does not rest in a bronchus. It is best that the catheter be passed in until it meets resistance, and then withdrawn about 5 cm. (2 inches). This means that it usually enters the right bronchus and when it is withdrawn it lies about 3 or 4 cm. (1½ inches) above the bifurcation. A protecting cover of hard rubber or metal to prevent crushing the catheter should be placed between the teeth, and the catheter fixed so that it will remain in position. The catheter should be connected with the insufflation apparatus, and the anesthetic vapor pumped into the lungs.

The apparatus for pumping air through the tube into the lungs may be a simple foot bellows or a power-driven pump. The electrical motor is most satisfactory. The advantages of electrically driven air pumps over the foot bellows are obvious. The air supply is steady and anesthesia may be maintained in a uniform manner. The air containing the ether vapor should be turned into the trachea slowly until the manometer registers 20 mm. of mercury. From this time on the anesthesia is easily under control. The current of air should be interrupted several times a minute and the pressure allowed to fall so that the lungs may empty themselves and not be kept in a constant state of inflation. From 50 to 75 per cent. of the air should pass through the ether bottle to maintain equable anesthesia. At the end of the operation the ether should be cut out, and the lungs cleared with pure air.

This method of anesthesia is not difficult. The accidents which have been reported are inexcusable. Flooding the lungs by submerging the efferent tube in the ether, accidentally raising the pressure above 100 mm. with the result of causing rupture of the lung, wounding the trachea by introducing the tube by force, and causing emphysema by entrance of air into the tissues through the wound, are some of the accidents which should not have occurred.

Many modifications of the technic of insufflation are employed. A foot pump, a simple ether bottle through which the air bubbles, and a tracheal catheter suffice. In the hands of the skillful anesthetist this simple equipment seems adequate. Instead of a foot pump or electric motor, a tank of compressed air, air and oxygen, or oxygen may be used.

(For further discussion of insufflation apparatus, and technic, see Surgery of the Thorax, Vol. II.)

Conclusions Concerning Intratracheal Anesthesia.—As a method of anesthesia ether vapor pumped through a tube into the trachea has a more than limited field. Its chief value is in cases in which the chest is opened and differential pressure is desired. For operations in which the face mask would be in the way, intrapharyngeal anesthesia is to be preferred.

HYPNOTIC ANESTHESIA

It is possible to place a susceptible patient in the hypnotic state so that operations may be performed without pain. This has been done occasionally, but as yet it has not found general application. With drug anesthesia suggestion may be well combined, as is described above. It is possible to make the drug the smaller part of the anesthetic. A few drops of chloroform may be inhaled after the proper suggestions have been made concerning sleep and absence of pain, and the patient carried through an operation if suggestion is continued. When the incision is made the surgeon suggests that, "we will now apply some warm water;" and the use of similar explanatory expressions serve to keep the patient in a quiet state.

The possibility of producing complete *anesthesia by suggestion* is not to be considered seriously. Much humbug has been connected with it. Patients may be tranquilized by suggestion, and put in a better state of mind for the administration of an anesthetic, but without such an agent they can not be rendered insensitive to pain; when nerves are cut they experience pain. In the suggestive state slight operations may be done upon parts which have little sensation, such as the cervix uteri; but when sensitive parts are cut the patient has pain, and when a "few whiffs" of chloroform are given as an adjunct to hypnosis, it is the chloroform that is the more potent agent of the two.

LOCAL ANESTHESIA

The anesthetic methods thus far considered have all accomplished anesthesia by a general benumbing of the whole nervous system. Such an artificial palsy is associated with a considerable degree of interference with the vital functions of the nerves and nervous ganglia; and there is, therefore, a certain amount of hazard in general anesthesia. It is sometimes of advantage that the patient be relaxed and unconscious during operations; but in operations in which these are not desired, local anesthesia may be employed. Local anesthesia has the advantage that the lungs, heart, and other vital organs are not taxed, and that the patient remains conscious. It has the disadvantage that patience and skill are required in its administration, and the anesthetization is a part of the operation and requires to be administered by a surgeon.

A good knowledge of the anatomy of the part is essential, especially the position of the nerves and blood-vessels. It is often of advantage to combine local with general anesthesia, the patient being given an occasional light inhalation of chloroform. By combining an injection of morphin with local anesthesia and a little general anesthesia, severe operations may be done which would be impossible with ether alone.

Local anesthesia is especially desirable for small operations, operations upon the fingers, toes, and external genitals; although it may be used in most of the major operations such as for hernia, gastrotomy, amputations, and the removal of tumors. The most satisfactory method is by the use of certain drugs, dissolved in salt solution, which are brought into contact with the nerves either at their peripheral distribution or at their trunks. The most useful of these agents are cocain and novocain. Local anesthesia enables the surgeon to operate alone and without assistance, taking as much time as is necessary for painstaking work.

For **anesthetizing mucous membranes** it only requires that the agent in solution be brought into contact with the surface of the membrane. This may be done by injecting the solution, as in the urethra; by applying it with a pledget of gauze, as on the tongue; by spraying with an atomizer, as in the nasopharynx; or by dropping with a pipet, as in the eye. For such applications solutions of 1 to 4 per cent. of cocain are employed, the surgeon always calculating that the patient shall not absorb more than the maximum dose of the drug. This may be called **surface contact anesthesia.**

Mucous membranes where possible should be washed with salt solution and dried, before applying the anesthetic. After the operation cocain should be washed off with salt solution. For a small area some surgeons prefer to use pure cocain made into a syrup with adrenalin solution 1:1000. When the tissues of a given area are anesthetized by injecting the tissues, it is called **regional anesthesia. Infiltration anesthesia** consists in infiltrating the tissues for a wide extent with a very weak solution of analgesic agent.

Terminal anesthesia is secured by injecting a nerve trunk which provides sensation for a terminal part or by infiltrating all of the tissues of a limb so that a peripheral anesthesia is accomplished. When a nerve is injected it is blocked from carrying centripetal impulses, and is thus cut off from the central nervous system.

The Scope of Local Anesthesia.—The sensations of pain, pressure, heat, and cold have to be dealt with. The internal thoracic and abdominal organs are supplied only by the vagus and sympathetic nerves. They, therefore, have no sensation of pain, pressure, heat, or cold. The parietal peritoneum, both posterior and anterior, is very sensitive. This sensation is derived through the lower seven intercostal nerves, the lumbar, and the sacral nerves. The center of the diaphragm is supplied by the phrenic nerve. It is possible that some parietal spinal nerves may enter the mesentery for a short distance. Traction upon the viscera causes pain because of the parietal nerves. The peritoneal coat of the bladder is not sensitive, but traction upon the bladder affecting the basilar parietal nerves causes pain. The kidney after it has been detached from the parietal structures may be handled without pain. The ureter is painless, but its covering of peritoneum is very sensitive. The same is true of the gall-bladder and ducts. The serous coverings of the testicle and vas deferens are sensitive, but the organs themselves are without sensation.

The heart and lungs are without pain sense, but their parietal connections are very sensitive. Such glands as the thyroid and the lymphatics of the neck are without sensation after they have been freed from their sensitive capsules. The same is true of the esophagus and trachea. The brain, pia, and arachnoid are without pain sense. The dura mater is not sensitive over the convexity of the brain, but at the base and under the occipital bone it is capable of pain. Pulling the dura from below is painful.

Bone and cartilage are not sensitive to pain excepting as to the periosteum and perichondrium, sensory nerves traversing bones (as the inferior dental) and mucous membranes of sense organs lining bones (as the middle ear, antrum of Highmore and frontal sinuses). The marrow and the medullary canal are without sensory nerves; but articular synovial membrane is very sensitive.

The skin of the entire body and the mucous membranes near the orifices are sensitive to all forms of pain. Connective tissue, muscles and fascia are sensitive to a slight degree, as they transmit the sensory nerve filaments. Tendons are without sensation except at the place of connection with the periosteum. Blood-vessels are sensitive so long as they are attached to connective tissue, but after they have been dissected free, their sensory connections are destroyed.

Neoplasms and granulation tissue have no sensation, but if the tissues in which they grow are sensitive, pulling or compression will cause pain.

It is thus seen that most of the structures of the body are without pain sensation. The skin and the abdominal and thoracic parietes are the sensitive parts. Once the skin and periosteum are penetrated, the brain may be cut without anesthetic. Bones which have been uncovered may have sequestra removed and the medullary cavity scraped. The lungs, heart, liver, kidneys, spleen, intestines, and stomach may be incised and sutured without sensation, provided traction and pressure upon their parietal connections are not made.

As the nerves emerge from the subdural space they become covered with a sheath which is a continuation of the dura mater. This becomes thinner as the nerves approach their peripheral distribution. The terminal

twigs have no sheath, and are accordingly most easily penetrated by the anesthetic agent. Tissues, such as the skin and periosteum, which contain only terminal nerve filaments are most easily anesthetized by infiltration. The skin can be rendered insensitive by cocain solution as weak as 1:20,000 or novocain 1:1000. Novocain of a strength of 1:800 is entirely adequate for skin infiltration.

The Technic of Local Anesthesia.—The *technic* for the hypodermic, endermic and diffuse injecting of local anesthetic solutions requires a sterilized syringe. The glass hypodermic syringe with glass piston or with asbestos packing (Fig. 36) and the metal syringe are the best, and are least damaged by boiling. For strong solutions the syringe should hold 1 or 2 c.c. of fluid; for weaker solutions the capacity of the syringe should be 5 or 10 c.c. An assortment of long sharp needles should be at hand, from 0.5 to 0.9 mm. in diameter and from 25 to 125 mm. long.

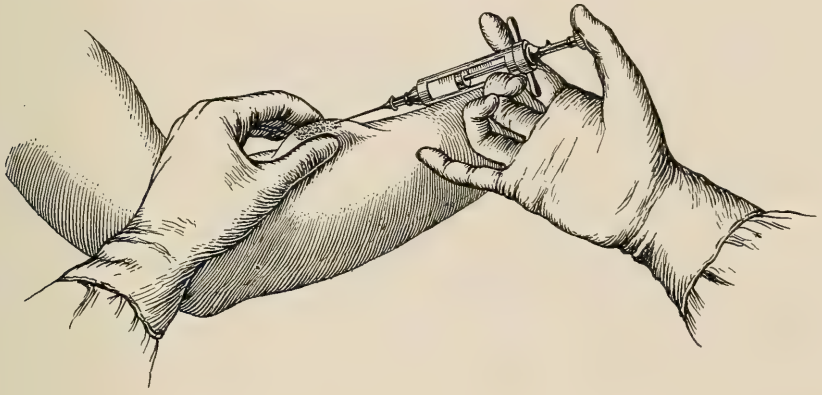


Fig. 72.—Intradermal Infiltration after Allen.

The preparation of the patient requires only that he should be in the best possible state of mind and body. A light meal may be eaten at the regular meal time preceding the operation. If the patient is nervous or fearful morphin may be given.

For anesthetizing the skin, the field of operation is prepared with all the aseptic precautions. For simple incisions, the solution is usually injected in the line in the skin where it is desired to make the incision. The surgeon marks with his eye where he proposes to cut. The needle is inserted obliquely into the skin, and a drop of solution injected, not into the subcutaneous tissue but directly into or against the deep layer of the skin. A slight blanching will be seen through the skin where the fluid appears. The very first injection should be made with a sharp fine needle. For cutaneous infiltration, the needle may be withdrawn after each whitened area is created, and reinserted near the edge of the area. This gives the best skin anesthesia (Fig. 72).

For hypodermic infiltration, the initial wheel of infiltration is made in the skin. Then, with the point of the needle now kept close to the skin, the needle is moved along to the edge of the blanched area and a second little drop injected. This is continued until the needle has reached its full length or until the line of anesthesia is long enough. The needle is then withdrawn and reëntered at the end of the anesthetized line or drawn back until its point is nearly ready to emerge from the skin, when it can be re-

versed and passed in the opposite direction without making another puncture of the skin.

In making deeper injections pains should be taken to avoid injecting into a blood-vessel. This accident may be prevented by using a blunt needle in deep injections. When injections are made near a blood-vessel, the needle should be attached to an empty syringe, and after its introduction suction should be made; if no blood is obtained it is evident that the point of the needle does not rest in a blood-vessel, and the injection may be made. By injecting the fluid at the same time that the needle is pushed along, the fluid tends to crowd blood-vessels aside.

A line somewhat more than twice the length of the needle can be anesthetized with one puncture of the skin, and with only the point of a single prick. If it is desired to continue the line, the needle may be inserted into the end of the already anesthetized line, and this continued indefinitely (Fig. 73). Only the smallest possible amount of solution need be injected,

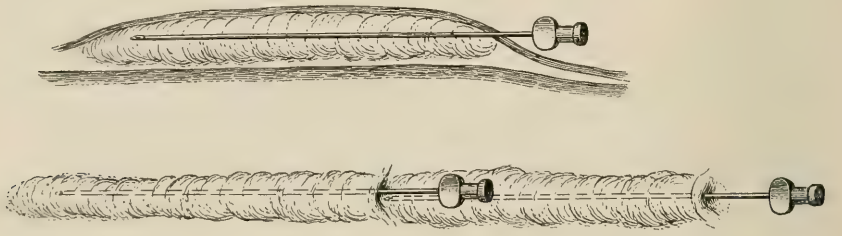


FIG. 73.—SUBCUTANEOUS INFILTRATION.

for anesthesia of the skin is only required in the very narrow line to be incised by the knife. A little rubbing or kneading will cause a wider diffusion of the fluid and its closer contact with the nerve terminals.

After novocain injections, half an hour is required before anesthesia is fully established. The patient may be sent back to bed during this half hour. The anesthesia of most drugs lasts from twenty to forty minutes. The pain of the first prick of the needle may be prevented by making firm pressure upon the spot for two minutes, by spraying the spot with a little ethyl chloride, by applying ice or a drop of phenol. The sharper and smaller the needle, the less will be the pain.

For anesthetizing the planes of incision for removing a tumor, the injections are made around the field of operation, and into the tissues under the tumor (Fig. 74). For deep injections, one or more points of skin infiltration should be made. These serve as "stations" through which the needle may be passed in many directions (Fig. 75).

For anesthetizing a wound, the anesthetic should be injected from several "stations" around the wound until the whole area is surrounded by anesthesia (Fig. 76). For wounds in dense tissues such as the palm of the hand, injection of the supplying nerve trunk in the arm is much more satisfactory.

In **operations upon the extremities** the absorption into the circulation is delayed by constricting the member above the point of injection, thereby closing the blood-vessels and temporarily stopping the circulation. This is done by allowing the blood to run out of the member by elevating it and then encircling it with rubber bandage or tubing. This is desirable in the arms, legs, fingers and toes. The anesthesia lasts as long as the constriction remains. The anesthetic agent may be kept from entering the general circulation until after the operation, and then, if so desired, may be made to enter slowly.

The injection of the anesthetic directly into the **nerve,** supplying the part with sensation, is one of the most satisfactory methods. For example, take the great sciatic nerve. The thigh is constricted, after allowing the blood to run out, and the nerve is exposed along its course by anesthetizing the skin as above described. The needle is then passed under the sheath of the nerve and injections made; after which, injections are made directly into

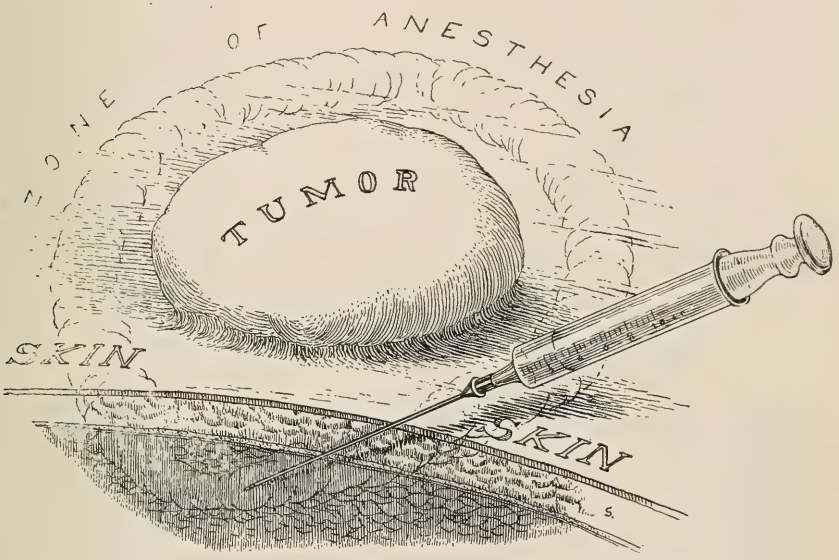


FIG. 74.—INJECTING TISSUES AROUND A TUMOR.
Injection should also be made under the tumor.

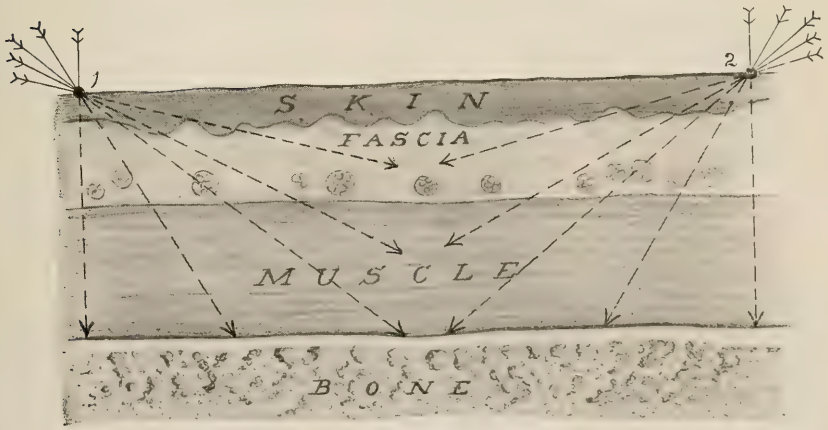


FIG. 75.—INFILTRATING DEEP TISSUES.
Note that this is done through the fewest possible skin punctures. Each place of skin penetration is called a "station," 1 and 2. (*After Allen.*)

its substance until its whole thickness is infiltrated with the solution. A 1 per cent. cocain solution is used. This results in complete anesthesia of the parts supplied by the nerve lasting twenty-five to thirty minutes, and amputation or other major operation can be done without pain or shock. Where the parts are supplied by more than one nerve, the different nerves

may each be treated in this way. Constriction is used only when it is desired to make a prolonged operation. Smaller nerves or nerves which the surgeon prefers not to expose may be anesthetized by injecting the surrounding tissues all about the nerve.

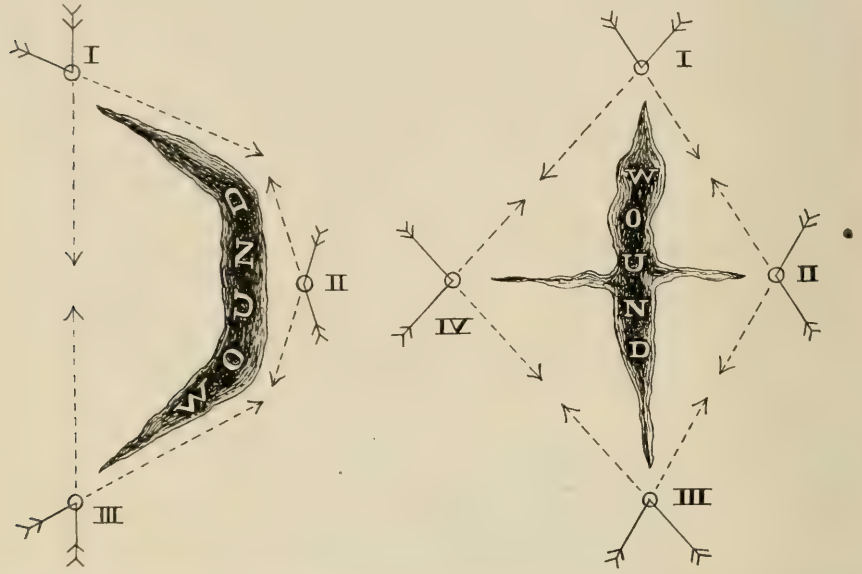


FIG. 76.—METHOD OF SURROUNDING A WOUND WITH A ZONE OF ANESTHESIA INTRODUCED THROUGH SKIN "STATIONS," I, II, III AND IV.

The method of **general infiltration** consists in injecting a larger amount of highly diluted anesthetic throughout the tissues. For this operation I have employed with satisfaction an apparatus which injects the solution

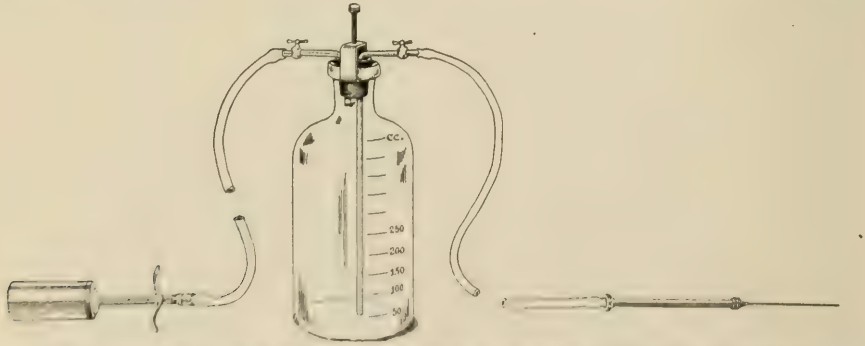


FIG. 77.—APPARATUS FOR MASSIVE INFILTRATION WITH WEAK SOLUTIONS.
Air pressure upon the surface of the fluid gives even and elastic injection. This same apparatus is used for intravenous infusions.

by means of the elasticity of compressed air (Fig. 77). A syringe of large capacity answers well.

Local venous anesthetic infusion is employed as follows: The blood is expelled from the limb by compressing it from below upward by the rubber

bandage. Elastic constriction, compressing veins and arteries, is made above the field of operation, and similar constriction below the field of operation (Fig. 78). A subcutaneous vein is opened just below the upper constricting band, and a canula inserted in the vein. It should be the sort of canula used in infusion. In the arm the basilic vein and in the

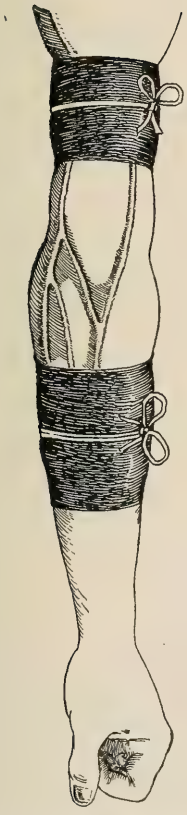


FIG. 78.—ARM PREPARED FOR INTRAVENOUS LOCAL ANESTHESIA BY RUBBER BANDAGE CONSTRICTION.

A simple piece of rubber tubing or a bandage may be used for this purpose.

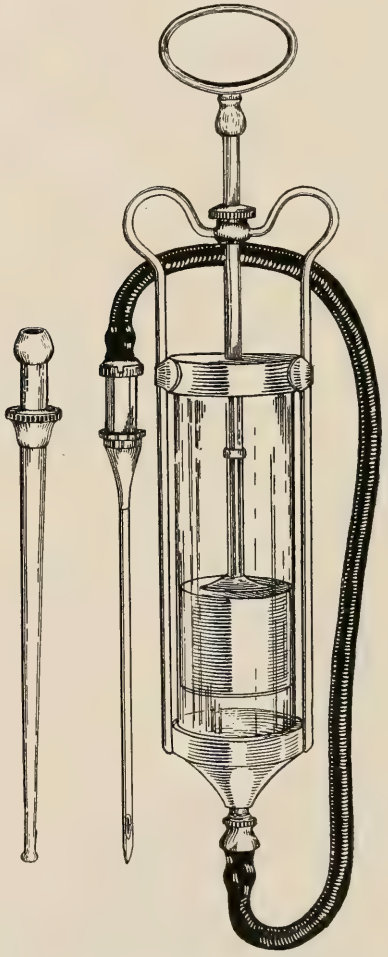


FIG. 79.—SYRINGE FOR INJECTING INTO VEIN

For local intravenous infusion anesthesia, the blunt-ended canula, which can be tied in, is used instead of the needle, because of the increase of pressure which is created in the vein.

leg the internal saphenous is best. The solution used is 0.5 per cent. of novocain in normal salt solution. Other drugs may be employed. The solution is injected toward the periphery with a large syringe (Fig. 79). For resection of the knee in adults 80 to 100 c.c. of solution are required. For the elbow 50 to 80 c.c. suffice. The anesthetic must be dissolved in physiological

salt solution. Adrenalin is not to be used. Anesthesia *between* the two constrictions takes place in about five minutes, and *beyond* the lower constriction in ten or twenty minutes. It lasts about seven minutes after removal of the constrictions. The canula which fits into the vein should be grooved so that two ligatures may close the vein about it. The vein above should be tied. All of the connections must be water tight, as considerable pressure is sometimes required to force the fluid past the valves of the veins.

The anesthetic agent may be washed out of the vessels after the operation by removing the peripheral bandage and slowly loosening the central bandage until the arteries are opened but the veins still compressed, or until the limb begins to grow pink and the wound bleeds. The central bandage is then tightened to compress the arteries, and the wound closed. When a large amount of anesthetic is used the canula may be left in the vein and before closing the wound the veins of the operative area washed out with salt solution. It is not necessary to remove the blood from the whole limb as was practical by Bier. The limb may be elevated to allow gravity to remove some of the blood; then a constricting elastic band is applied above the lesion. From this band upward an elastic bandage is used to empty the vessels toward the trunk for a distance of 10 to 20 cm. (4 to 8 inches) at the upper limit of which a second constricting band is applied. In this bloodless zone the anesthetic is injected to anesthetize the parts beyond.

During the operation if the upper bandage becomes painful another constriction may be made below it or above it and the first one removed.

The anesthesia lasts as long as the upper bandage remains; and ends two to seven minutes after its removal.

Arterial infusion is by the same principle. Ransohoff applied an elastic bandage about the arm below the insertion of the deltoid, exposed the brachial artery under infiltration anesthesia, injected 1 c.c. (15 minims) of a 2 per cent. cocain solution into the artery, and, absolute anesthesia being present in two minutes, did an antebrachial amputation without the knowledge of the patient (Lancet-Clinic, Cincinnati, Aug. 7, 1909).

Conclusions Concerning Intravenous Local Anesthesia.—This is not always satisfactory. General anesthesia sometimes has to be added. Too tight bandages increase the discomfort and hazard. It is not adapted to general use, but may find application in special cases.

Anesthetic Agents.—*Cocain*, the strongest of local anesthetics, is used alone or combined with other substances. It is a white crystalline powder, freely soluble in water and alcohol. Its effect on nervous structures is to cause temporary paralysis. It enters into combination with the protoplasm of the nerve cells. The products of this combination are then dissolved and carried away by the circulation. In the event of cocain poisoning, with respiratory paralysis, if artificial respiration is practised, until the products of the combination are carried away life may be saved. The danger of the drug is that a poisonous amount, a concentrated dose, may reach the basilar centres at one time. This is the danger of injecting into a vein or artery. Injected into connective tissue, from which it is slowly absorbed, 0.06 Gm. (1 grain) may be regarded as a maximum dose. Patients have been killed by smaller dose than this. Dangerous symptoms have followed doses as small as 0.01 Gm. (1/6 grain). My own practice has been to limit a healthy adult to 0.05 Gm. (3/4 grain). I have taken hypodermatically for experimental purposes 0.06 Gm. (1 grain) without harm. To be on the safe side the patient should be kept in the horizontal position after the injection until the cocain has been eliminated.

When injected into a nerve there is no evidence indicating that cocain produces any permanent changes. Its temporary selective action is on the sensory fibres. It should be used with normal salt solution, otherwise the injection causes pain.

The hydrochlorate of cocain is generally used. It has the disadvantage that it is a poisonous drug. Solutions of 1 to 4 per cent. applied to the eye or to a mucous membrane produce complete local sensory paralysis of the surface to which it is applied. For anesthetizing the skin, it is necessary that the solution be injected subcutaneously. For this purpose solutions of from $\frac{1}{10}$ to 4 per cent. are used. Solutions do not keep well, and for this reason should be made up fresh. When a small amount is used the solution may be made more permanent by the addition of a little phenol ($\frac{1}{2}$ per cent.). In cases, in which absolute sterility is desired the solution of the drug may be boiled. Prolonged boiling causes a loss of some of the drug, but it may be heated to 100°C. (212°F.) for a few minutes without harm. The drug may also be sterilized by covering it with ether and allowing the ether to evaporate.

The action of cocain is aided by using normal salt solution. This also has the advantage that it is less irritating to the tissues when injected than plain water. In using this, or any other drug it is well to decide the amount which the patient might be allowed and then try to keep well under this allowance. Strong solutions (2 to 4 per cent.) are rarely necessary for injection into the tissues.

Combination with morphin or hyoscin is of advantage. A tablet composed of cocain hydrochlorate 0.03 Gm. ($\frac{1}{2}$ grain) morphin hydrochlorate 0.008 Gm. ($\frac{1}{8}$ grain), and sodium chloride 0.06 Gm. (1 grain), represents a good combination. One of these tablets dissolved in 30 c.c. (500 minims) of sterile water gives a $\frac{1}{10}$ per cent. solution, which is of adequate strength for an extensive operation. *Schleich's solutions* for infiltration anesthesia are made as follows:—No. 1 (strong): Cocain hydrochlorate 0.12 Gm. (2 grains), morphin hydrochlorate 0.015 Gm. ($\frac{1}{4}$ grain), sodium chloride 0.12 Gm.(2 grains), sterile water 60 c.c. (1000 minims). No. 2 (normal): Cocain 0.06 (1 grain), morphin 0.015 Gm. ($\frac{1}{4}$ grain), salt 0.12 Gm. (2 grains), water 60 c.c. (1000 minims). No. 3 (weak): Cocain 0.006 Gm. ($\frac{1}{10}$ grain), morphin 0.015 Gm. ($\frac{1}{4}$ grain), salt 0.12 Gm. (2 grains), water 60 c.c. (1000 minims).

Where a smaller amount of fluid is used, as in short incisions or for injecting nerves a stronger solution may be employed. For anesthetizing a small area in the nose or mouth, the pure crystals of cocain may be placed on the dried mucous membrane, and washed off after the operation. Or a syrupy fluid may be made by a few drops of adrenalin added to the pure crystals. Adrenalin may also be combined with cocain with advantage as it contracts the vessels, delays the absorption of the cocain, and renders the field of operation less bloody. It is dispensed commercially in a 1 : 1000 solution. The 1 : 1000 solution of adrenalin may be added to 100 or more parts of salt solution. A practical method is to employ cocain for the skin incision and, when general infiltration is required, one of the less toxic agents for the less sensitive tissues. Cocain and the other anesthetics act poorly in inducing anesthesia in inflamed or infiltrated tissues. In such tissues the addition of adrenalin is of decided value. Often it is best to begin the anesthetization in the adjacent uninflamed tissue.

Eucain has much the same action as cocain and may be used in five times the amount. It may be sterilized by boiling. β-Eucain is used. Its chief objection is that it causes a dilatation of the blood-vessels and provokes

bleeding. This action may be somewhat neutralized by combining it with adrenalin, although the adrenalin decreases its anesthetic power.

Novocain is similar to cocain, but 5 or 7 times less toxic. Its strength is also less. It is not destroyed by boiling or exposure to light. It is destroyed by free and carbonate alkalies, and, therefore, can not be used with alkaline glass or instruments boiled in soda solution. It is the least toxic of the local anesthetics. Its effects are very evanescent, but with adrenalin it becomes very effective. Employed in twice the strength of cocain it may take the place of that dangerous drug for all uses. As much as 0.6 Gm. (10 grains) has been injected without harm. It has quite displaced cocain in most clinics, except for local application to mucous membranes.

It is not irritating to the tissues and does not lower blood-pressure. It effects the motor nerves but slightly. In the subarachnoid space it causes but slight paralysis of the leg muscles. A 5 per cent. novocain solution has about the same specific gravity and the same freezing point as blood-serum and cerebrospinal fluid.

Novocain at the present time may be regarded as the most useful local anesthetic agent. Several strengths may be made. The following are convenient solutions:

No. 1. (1:400)	Novocain	0.25 Gm. (4 grains)
	Physiologic salt solution	100.00 c.c. (3 ounces)
	Adrenalin (1:1000)	0.3 c.c. (5 minims)
No. 2. (1:200)	Novocain	0.25 Gm. (4 grains)
	Physiologic salt solution	50.00 c.c. (1½ ounces)
	Adrenalin (1:1000)	0.3 c.c. (5 minims)
No. 3. (1:100)	Novocain	0.1 Gm. (1½ grains)
	Physiologic salt solution	10.0 c.c. (150 minims)
	Adrenalin (1:1000)	0.3 c.c. (5 minims)
No. 4. (1:50)	Novocain	0.1 Gm. (1½ grains)
	Physiologic salt solution	5.0 c.c. (75 minims)
	Adrenalin (1:1000)	0.3 c.c. (5 minims)

These proportions may be varied to meet the needs of the operation. The amount of adrenalin may be increased to double the above. Solution No. 2, with the amount of saline doubled makes No. 1. Solution No. 4, with the amount of saline doubled, gives No. 3. Solution No. 1 (1:400) is used for infiltration anesthesia, and may be injected in amounts up to 100 c.c. (3 ounces) or more. No. 2 and No. 3 are used for endoneural injections. No. 4 is used for endoneural injection of a large nerve which is to be severed, and for the perineural injection of nerves to be penetrated by the anesthetic.

Tropocain (tropacocain) is soluble in water. It is non-irritating; it may be boiled; it is one-third as toxic as cocain; and acts as a vasodilator. Anesthesia occurs sooner than with cocain and lasts longer. Adrenalin counteracts its effect. Its regular dose is 0.03 to 0.06 Gm. (½ to 1 grain), but it may be increased to 0.12 Gm. (2 grains). It is useful in spinal anesthesia.

Stovain is readily soluble, is acid in reaction, and has antiseptic properties. It may be boiled. It is less poisonous than cocain; its effect is more evanescent. It acts as a vasodilator. Its effect upon motor nerves is much more pronounced than the other anesthetics. It paralyzes the muscles supplied by the nerves acted upon by it. In operations on the abdomen, perineum, and sphincters, this is of decided advantage. As a spinal anesthetic it is dangerous if allowed to reach the higher centres. Its regular dose is 0.06 Gm. (1 grain). It is used in 2 to 5 per cent. solutions. In the nose it may cause troublesome bleeding.

Alypin is used in 2 to 10 per cent. solution. I have employed it with much satisfaction for infiltration purposes in amounts up to 0.12 Gm. (2

grains). In the nose it may be used in 10 to 20 per cent. strength. It is a vasodilator and tends to cause bleeding. It acts much slower than cocain. A 4 per cent. solution is used in the eye.

Holocain hydrochloride is not decomposed by boiling. It is used chiefly in the eye in 1 per cent. solution. It is neutralized by alkalies.

It is slightly more toxic than cocain. In the eye, its effect lasts about fifteen minutes. It is mildly antiseptic.

Akoin is similar to holocain. It is decidedly antiseptic. It is less anesthetic in its action, and slightly more toxic than cocain. Its anesthesia is prolonged, lasting several hours. It is irritating and can not be used in solutions stronger than 0.2 or 0.5 per cent. It is decomposed by alkalies. It may with advantage be used combined with other anesthetics.

Nirvanin is mildly antiseptic, not decomposed by heat, and is less toxic than cocain. It is about one-tenth as powerful as cocain, and the duration of its action is shorter. It is rarely used.

Anesthesin is almost insoluble in cold water and but slightly soluble in hot water. It is freely soluble in alcohol, fatty oils, ether and benzin. Its especial value lies in the facts that it is non-irritating, almost non-poisonous, and is decidedly anesthetic. It acts more slowly than the soluble agents on unbroken mucous membrane, but it is decidedly effective. It is so non-irritating that it can be applied freely and in strong solutions to the most sensitive tissues. In *tuberculous laryngitis,* it relieves pain when applied by insufflation, by 10 per cent. emulsion, or by 3 per cent. solution (water with 45 per cent. alcohol). In ulcer of the bladder or urethra, stomach or duodenum; in cystic calculi; in anal ulcer, it relieves pain. After operations on the rectum, a 20 per cent. ointment will prevent pain. In painful chancroids after cauterization the pure powder will stop the pain. A 10 per cent. ointment applied to the skin relieves the pain of pruritis. It is the most valuable agent for topical application.

Apothesine has a low degree of toxicity. As much as 0.6 Gm. (10 grains) of the drug has been injected in solution. A 1 per cent. solution is a highly effective anesthetic. Adrenalin 1:1000 solution may be added with advantage — 0.3 c.c. (5 drops) to 30 c.c. (1 ounce) of the apothesine solution. The anesthesia lasts for fully an hour.

Orthoform is similar to anesthesin except that it is irritant and toxic. It is, therefore, much less valuable.

Suboutin is slightly germicidal and is non-toxic. It is soluble in water up to 1 per cent. It is somewhat irritating when injected, and is much less potent as an anesthetic than cocain.

Propäsin is but slightly soluble in water but freely soluble in alcohol and ether. It is used as a 10 and 20 per cent. ointment on the skin. Its anesthetic effect when rubbed in is of long duration. It may be given internally in doses up to 0.2 Gm. (3 grains) several times daily.

Thymol is used in dentistry combined with novocain. A popular solution is novocain (1.5), sodium chloride (0.92), thymol (0.025), and distilled water (100.0).

Quinin and urea hydrochloride is a double salt of quinin and urea. It is soluble in its own weight of water and in alcohol, is astringent, hemostatic, and antiseptic. It is non-irritating when injected and produces anesthesia which lasts for several hours or days. When used locally in oil a 10 to 20 per cent. solution applied to ulcers or painful mucous membrane relieves pain. For local anesthesia, infiltration with a ¼ per cent. solution is effective. Any of the salts of quinin seem to have the same anesthetic power. They may be used in 1 or 2 per cent. solution, but when stronger than ¼ per cent.

they cause induration. Boiling does not destroy their efficiency. The drug may be used the same as cocain, but without fear of poisoning. The dose is the same as that of the other salts of quinin.

Too strong a solution causes a deposit of fibrin and occlusion of vessels; and may lead to sloughing. When ¼ per cent. solution is used the deposit of fibrin and induration of the tissues does not occur. This is the strength preferred when primary union is desired. A 10 to 20 per cent. solution is used in mucous menbranes and externally. A 1 to 3 per cent. solution is used for tonsillectomy. Not only is the drug itself hemostatic, but the fibrinous exudate also acts to prevent bleeding. The solutions are best made with plain sterile water instead of salt solution.

For operations about the anus this drug is most effective, as the prolonged anesthesia insures comfort after the operation. Here it is the anesthetic of choice. Hernia is successfully operated upon with a ¼ per cent. solution. By pouring some of the warmed solution on the peritoneum of the sac it is rendered insensitive.

A 1 per cent. solution injected into the tissues produces immediate and perfect anesthesia which lasts four or five hours, but induration occurs. The ¼ per cent. solution causes just as good anesthesia after a few minutes without induration. Even weaker solutions give complete anesthesia. The 1 and ½ per cent. solutions cause anesthesia which continues perfect for four or five days. There is loss of sensation from the latter for ten days and from the former for two weeks.

The fibrinous exudate is outside of the vessels. It is desirable to prevent bleeding. It does not interfere with the development of granulations. Its hemostatic property may be taken advantage of when desired.

Magnesium salts (magnesium sulphate and chlorid) applied to a nerve blocks conductivity, both of sensory and motor impulses. The effect lasts for several hours. When injected into the tissues, blood or subarachnoid space these salts are very toxic and must be used only in very small doses. They are used in tetanus to cause muscular relaxation.

Poisoning from the toxic local anesthetics is not uncommon. An overdose of cocain, for example, produces respiratory and cardiac depression, air hunger, and psychic depression. The administration of ether by inhalation on an open mask acts promptly as a physiologic antidote. Inhalations of ammonia, and injections of camphorated oil are also useful.

Isotonic Solutions.—Solutions of salt which have a specific gravity similar to that of the serum of the tissues are called isotonic. Fluids injected into the tissues should be isotonic and have a temperature not very different from that of the blood, otherwise the fluids do injury to the tissues.

A *hypotonic solution* extracts salts from the tissues and gives off water, thus altering the ratio of salts in the affected tissues. In the case of a nerve, the tissue becomes swollen and its structure altered by the loss of salts. A *hypertonic solution* extracts water from the tissues, causes an increase in the ratio of salt, and produces shrinking. The freezing point of the blood is −0.55° to −0.57°C. (31°F.) A solution having a freezing point of about −0.56°C. (31°F.) is isotonic with the blood. A solution of sodium chlorid which is physiological for human tissues must contain 0.92 per cent. of salt. Such a solution when injected slowly into the tissues at body temperature causes no pain, chemical change or irritation. It is capable only of causing pressure.

If the percentage of salt is reduced, a solution produces pain and leaves the nerves anesthetic, when the reduction (hypotonicity) is 0.55 per cent. or less. The abstraction of salt from the nerves and the swelling with water

cause pain and then anesthesia. The pain and anesthesia increase as the reduction of salt continues. Pure water injected into the tissues is very painful; but the pain soon ceases and is followed by anesthesia which lasts for fifteen minutes. It is possible for greatly diluted solutions to cause permanent destruction of tissues. Superficial necrosis may follow the injection of pure water under the skin.

With hypertonic solutions, the absorption of water from the tissues leaves them under the influence of an excessive ratio of salts. The injection of a solution stronger than 2.5 per cent. causes pain, which is followed by anesthesia. The intensity of this reaction increases as the percentage of salt is increased. The pain from the injection of a 10 per cent. salt solution is very severe.

Sterile Water Anesthesia.—This may be accomplished by using *plain sterile water*. Anesthesia is produced by the hypotonicity of the fluid, which extracts salts from the sensory nerves to such a degree as to inhibit their functions. Pain is caused before the anesthesia sets in. The pain is not so great as would be the incision of the unanesthetized tissues; hence this method of anesthesia may be used for short operations in patients who are willing to suffer the slight smart caused by the fluid.

The injection of *normal salt solution* (isotonic, 0.92 per cent.) gives a slight degree of anesthesia if the amount is sufficient to cause pressure upon the nerves. It is purely a mechanical function. If a line of such injection is made into the skin, in amount sufficient to make the skin tense, the compressed area may be incised in about three minutes without causing pain. Operations for hemorrrhoids and fistula are done under this method.

Adrenalin (epinephrin, suprarenin, paranephrin, epinephrin) is a powerful vasoconstrictor. It is used in connection with local anesthetic agents. It must be kept away from the light as it is easily decomposed. It should be preserved in a dark bottle in a dark room and hermetically sealed. As it decomposes, the solution first becomes pinkish, then brownish-red, and then turbid. The surgeon will secure satisfactory results only from a clear fresh solution. It should be borne in mind that adrenalin not only causes pronounced local contraction of the unstriped muscle fibres and, therefore, narrowing of the lumen of blood-vessels, but as it is absorbed it acts upon all of the circulatory system and causes an increase of blood-pressure. Thus while locally it tends to close the mouths of bleeding vessels and check hemorrhage, while if allowed to become absorbed it raises the blood-pressure and tends to force the clots out of the mouths of the cut vessels and cause a renewal of hemorrhage. Unless vessels are properly ligated secondary hemorrhage may occur after the use of this drug. The action of the drug seems to be directly upon involuntary muscle fibres. Its most pronounced action is upon the subcutaneous vessels and the vessels of superficial parts; it affects the vessels of the stomach and intestine to a lesser degree; and seems to have no effect on the vessels of the lungs. In superficial tissues its action is so strong that it practically closes the capillary circulation and causes the tissues to become blanched. This action lasts for about an hour.

The constitutional effect of adrenalin is very powerful. Like cocain it must not be admitted to the general circulation in concentrated doses. If injected into a vein it should be in very diluted solution. The maximum dose of the 1 : 1000 solution may be regarded as 0.6 c.c. (10 minims). For local use the equivalent of 0.06 to 0.6 c.c. (1 to 10 drops) is used. This is employed in solutions not stronger than 1 : 10,000. Usually 1 : 50,000 or 1 : 150,000 is used for injecting nerves, and 1 : 200,000 or 1 : 500,000 for infiltration.

Adrenalin greatly enhances the value of local anesthetics when injected with them as it so stops the local circulation that the anesthetic is but slowly absorbed. It is locked in the tissues much the same as when held by a constricting bandage. There are some anesthetic substances which diminish the vasoconstricting power of adrenalin. Among these are tropacocain and beta-eucain. The action of stovain is but little increased by adrenalin. Cocain and novocain have their anesthetizing power greatly increased by adrenalin.

Local Anesthetization for Special Operations.—*The Head.*—The head is largely supplied with sensation by the trifacial nerve and the cervical plexus. Operations may be done on the scalp by injecting novocain and

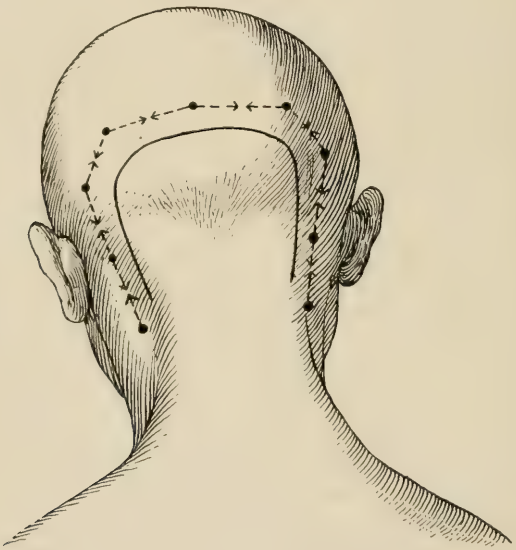


FIG. 80.—POINTS OF INJECTION AND LINE OF INFILTRATION FOR ANESTHETIZING SCALP AND PERIOSTEUM FOR CRANIOTOMY TO EXPOSE CEREBELLUM.

adrenalin solution No. 1 beyond the line of incision (Fig. 80). The whole top of the scalp may be rendered insensitive by injecting a circle around the head. The main nerve trunk should be injected with solution No. 3 around the point of their exit from the skull. By injecting the regions of exit of the frontal, supraorbital, auriculotemporal, auricularis magnus, and the occipitalis minor and major, the areas respectively supplied by these nerves are rendered insensitive. The periosteum of the skull should be injected with solution No. 1. The dura over the dome of the skull does not need to be injected (Fig. 81).

Operations may be done in the forehead by injecting a horizontal line above the orbit. The occipital region may be anesthetized by injecting a line at the insertion of the trapezius and an arch above the incision. Mastoid operations require injections of the periosteum over the mastoid.

The face may be subjected to most of the surgical operations under local anesthesia. By adding an injection of morphin and a small amount of general anesthesia to the local anesthesia, the most extensive operations may be carried out. Double resection of the upper jaw has been done by a simple injection of the second division of the trifacial nerve in the sphenopalatine fossa, the needle being passed through the sphenomaxillary fossa. Plastic

operations about the face are done with facility under local anesthesia. The entire upper lip may be anesthetized by infiltrating the infraorbital nerves; and the lower lip by passing the needle into the mental foramen. Regional anesthesia may be secured by injecting around the line of incision (Fig. 82).

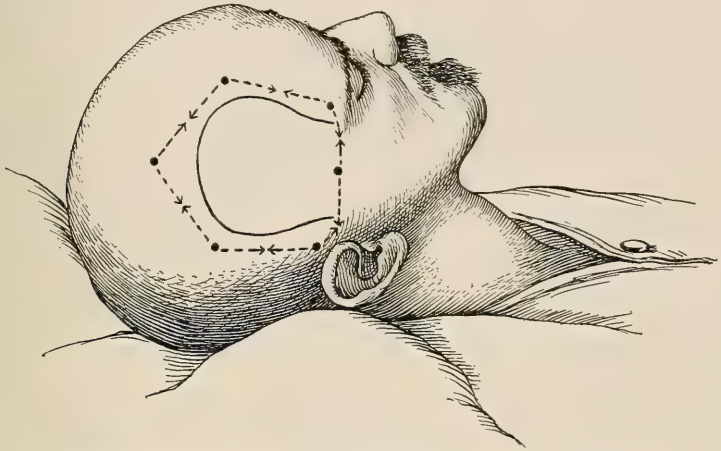


FIG. 81.—POINTS OF INJECTION AND LINE OF INFILTRATION FOR TEMPORAL CRANIOTOMY.

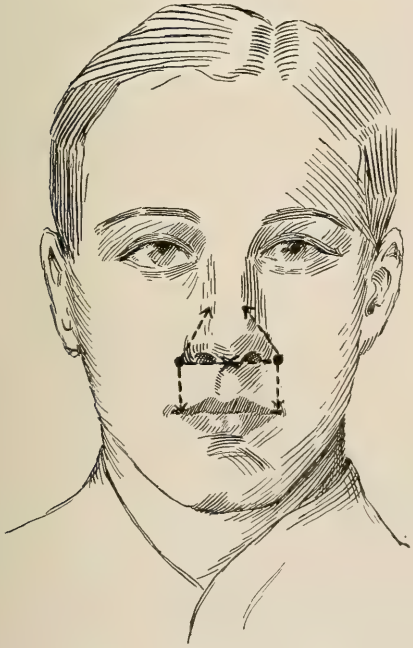


FIG. 82.—POINTS OF INJECTION AND LINES OF INFILTRATION FOR ANESTHETIZATION OF NOSE AND UPPER LIP. (*After Allen.*)

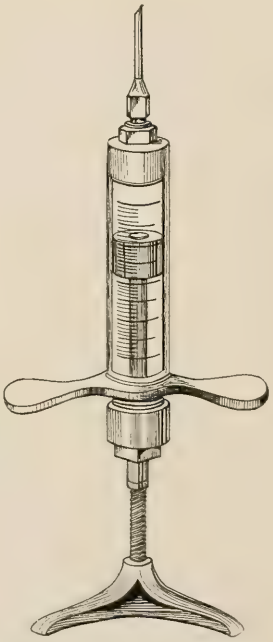


FIG. 83.—DENTAL SYRINGE FOR ANESTHETIC INJECTIONS IN DENSE TISSUES.

The extraction of teeth is done under novocain solutions No. 3 or No. 4. By making pressure on the mucous membrane and injecting the periosteum of the alveolar process, inside and outside, with novocain opposite the tooth.

extractions may be made with little pain. The injection of the periosteum should also be made around the margin of the socket, injecting also toward the root of the tooth. The abolition of all pain may be secured by injecting

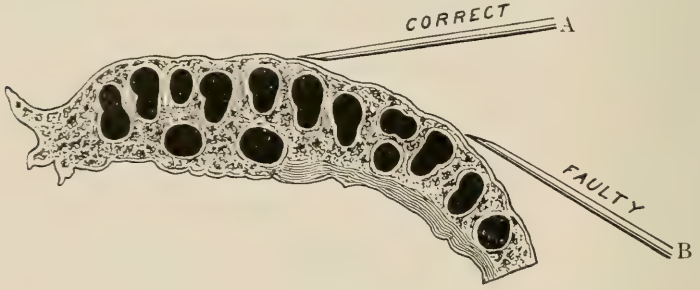


FIG. 84.—ALVEOLAR PROCESS.
A, Showing position of needle in order to anesthetize periosteum. *B*, Faulty position.

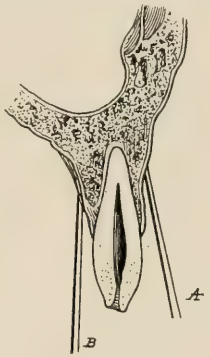


FIG. 85.—INJECTION OF ALVEOLAR MUCOSA AND PERIOSTEUM.
A, Outer side; *B*, inner side of alveolar process injection.

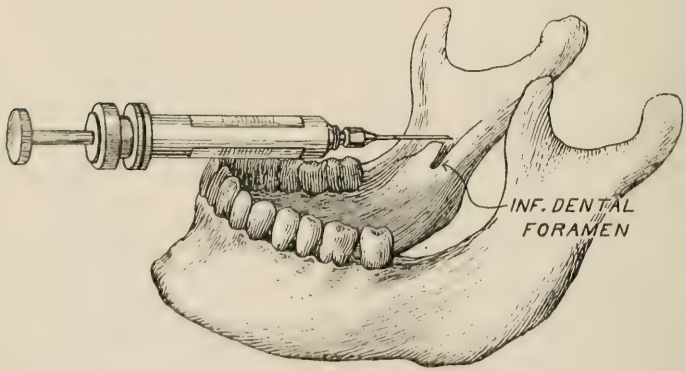


FIG. 86.—INJECTING INFERIOR DENTAL NERVE.
Showing positions of syringe and point of needle for injection.

the posterior dental nerve. Before entering the upper jaw the nerve lies under the mucous membrane of the mouth on the posterior surface of the jaw. To render the lower jaw insensitive the injection should be made at the opening of the inferior dental canal. The nerve enters the bone

midway between the anterior and posterior borders of the ramus and midway between the sigmoid notch and the lower border of the jaw. The nerve may be injected by introducing the syringe in the mouth (see Injection of Inferior Dental Nerve for Neuralgia, page 873). Novocain solution No. 4 injected around the nerve at its entrance into the bone gives complete anesthesia of half of the lower jaw.

Dentists use especially strong syringes to force fluid into the dense structure of the gums (Fig. 83). The opening of the needle should be as close to the bone as possible and not away from the bone (Fig. 84). The mucous membrane having been pressed is painted with iodin. The needle is then passed through the gum opposite the root of the tooth and the injection made as the needle passes in and finally under the periosteum. This should be done both on the palatine side and the buccal side (Fig. 85). The anesthetic should be injected also at the mouth of the tooth socket to force the fluid into the socket around the tooth.

Upper molars are best treated by making the injection in the posterior palatine canal. A long needle enters the mucous membrane high up about over the second molar tooth, and passes upward, backward, and inward, the syringe being kept well away from the bone. The point of the needle should be kept close to the convex surface of the maxillary tubercle until its posterior surface is reached. Here the superior dental nerve is reached before it enters the bone. About 4 c.c. (1 dram) of a 1 or 2 per cent. solution of novocain should be injected.

For dealing with several lower teeth the inferior dental nerve may be reached as it enters the inferior dental canal on the lingual side (see Injections for Trifacial Neuralgia, page 865).

The tongue may be anesthetized by injection of solution No. 3 along either side of the tongue at the floor of the mouth. The glossopharyngeal nerve lies on the posterior lateral aspect of the tongue just internal to the styloglossus muscle.

The palate is anesthetized by infiltrating the pterygo-maxillary fossa and making injections at the level of the posterior foramen of the palate.

The *nasal cavities* are best anesthetized with cocain applied to the surface with a pledget of gauze. The surface should have been washed with salt solution and dried before using the drug, and after anesthesia is secured the surface should be washed with sterile water to remove the cocain.

The *trigeminal nerve* may be injected by the same methods as are employed in the treatment of neuralgia. By such injections with anesthetic solutions, preceded by scopolamin and morphin, resections of the upper jaw may be carried out without pain or serious shock. (For all facial regions, see Injections of Trifacial Nerve, page 865.)

The *ear* can not well be anesthetized with cocain alone if the drum is intact. Cocain, combined with analin oil and alcohol, or with crystals of phenol and menthol in equal parts, is useful for analgesia preparatory to paracentesis of the drum. Better still is an oily suspension of anesthesin. For operations on the outer ear complete analgesia may be secured by infiltrating the tissues around the attachment of the ear and making deep injections as far as the lining of the external canal.

The Neck.—The interior of the pharynx and larynx may be anesthetized with cocain applied in a spray or directly by a swab. It may be used in 5 per cent. solution provided that not more than a safe amount of the drug is used in all.

The *larynx and trachea* may be anesthetized for all the procedures of surgery. *Tracheotomy* is easily done under local anesthesia by infiltration

in the middle of the neck. The mucous membrane is not painful, but irritable. Coughing and spasm may be prevented by applying cocain after it is exposed. *Laryngectomy* is done with novocain (0.25), sodium chloride (0.4), distilled water (100); to which is added 0.5 or 1 c.c. adrenalin (1:1000) for every 100 c.c. of solution. Preliminary tracheotomy is done under local anesthesia. Ten days later the larynx may be removed. About 45 c.c. of solution are injected on each side of the larynx for about 5 cm. opposite the middle of the sternomastoid muscle. A line of injection passes to the middle of the neck just below the hyoid bone along the thyrohyoid membrane. About 8 c.c. are required on each side for this superior injection. A similar amount is injected over the surface of the bone to block the superior laryngeal and descending hypoglossal branches. A transverse line

FIG. 87.—LINES OF INJECTION FOR LARYNGECTOMY. (*After Allen.*)

just below the field of operation is then anesthetized (Fig. 87). After the larynx has been exposed, the recurrent laryngeal nerves are injected. Finally as the operation proceeds the space between the larynx and esophagus is infiltrated.

The interior of the *trachea and bronchi* may be anesthetized by anesthesin, cocain, alypin or other of the local anesthetics, applied as a spray or on a swab, provided that the total amount used does not exceed a safe dose of the drug.

The *esophagus* need not be anesthetized for the passage of instruments unless dilatation is necessary. A stricture or ulcer may be treated with anesthesin or strong cocain solution provided the total amount of the latter used does not exceed a safe dose of the drug.

The *thyroid* is readily removed under local anesthesia. Any of the structures of the neck may be anesthetized with novocain No. 1. Tracheotomy, laryngotomy, and ligation of the carotids are done under this anesthetic. For *thyroidectomy*, an infiltrating injection should be made in the four corners at the entrance of the thyroid arteries, thus surrounding the field of operation with a ring of anesthesia. As the gland is exposed

and rolled out of its capsule, further infiltration, especially above and posteriorly, will be needed.

Cervical lymphatics may be removed under local anesthesia. The auricularis magnus, superficialis coli, and supraclavicular nerves emerge at about the middle of the posterior border of the sternomastoid muscle. A diffuse injection of No. 3 novocain solution should be made in this region.

The Upper Extremities.—The arms may be subjected to all of the operations of surgery under local anesthesia. For anesthetizing the whole arm and shoulder, the *brachial plexus* should be exposed under local anesthesia, and each trunk slowly injected with 0.5 per cent. novocain solution. Under such anesthesia as this intrascapulo-thoracic amputation can be done, with the addition of light general anesthesia while the scapular nerves are being cut. Complete analgesia of the shoulder and arm comes on in five or ten minutes after the injection. (see Brachial Plexus, page 890, and Nerves Supplying Upper Extremity, page 892). For operations on the forearm, wrist, or hand, the most satisfactory anesthesia is secured by directly cutting down upon the median, musculospiral, and ulnar nerves, and injecting each trunk. This can be done quickly, surely, and safely.

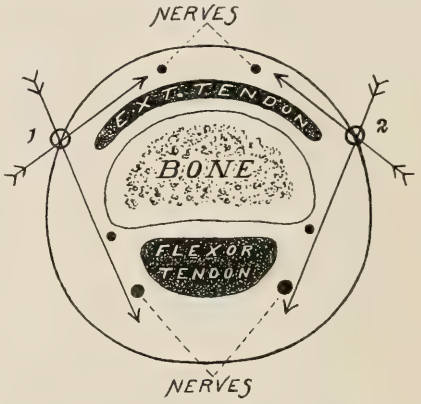


FIG. 88.—INJECTION OF FINGER.

Cross-section showing points of injection, 1 and 2, and direction of needle to reach dorsal and palmar nerves.

The nerves may all be injected at the wrist in the lower forearm by infiltration. The ulnar lies beneath the tendon of the flexor ulnaris; the radial passes beneath the tendon of the supinator longus; the median lies behind the palmaris longus; and the posterior interosseous lies deeply behind the extensor tendons.

For lower operations the surgeon should determine the nerve supply to the part, cut down upon the nerve trunks and inject them. Perineural infiltration may be done instead. This latter may be done successfully with such an easily located trunk as the ulnar nerve.

For operating on the fingers an infiltrating injection of novocain solution No. 2 or 3 is made around the base of the finger. When possible a constricting band may be used to cause retention of the anesthetic. The skin at the root of the finger is infiltrated first on the dorsal side a little above the web. The needle is then passed forward to the digital nerves, which lie on either side of the phalanx (Fig. 88). The hand is then elevated and the blood excluded by a rubber ring.

The Lower Extremities.—The legs are amenable to the same methods as are applied to the upper extremities. The antero-external aspect of the upper third of the thigh is anesthetized by infiltration injections with novocain No. 2 around the external cutaneous nerve, below Poupart's ligament and above the great trochanter. For the anterior surface of the lower two-thirds of the thigh injections should be made transversely in the subcutaneous tissues at the lower part of the upper third of the thigh. The entire anterior surface of the leg and the foot, exclusive of the toes, are anesthetized by perineural infiltrations around the peroneal nerve, back of the head of

the fibula, around the long saphenous nerve at the inner side of the knee, and connecting the two points by transverse subcutaneous infiltration.

By injecting the nerve trunks any operation may be done upon the parts supplied by the injected nerve. Skin grafting, operations for varicose veins, resection of joints, and operations for fracture of the patella may be done. The foot and most of the leg may be anesthetized by a perineural injection around the internal saphenous nerve at the inner side of the knee and by exposing the sciatic nerve above the popliteal space and injecting it with No. 3 novocain solution. All operations below the knee may be done by trunk injections. When near the knee, the external cutaneous, anterior crural, and sciatic are injected. Below the upper third of the leg, it is sufficient to inject the sciatic at the buttock and the long saphenous. The latter nerve may be infiltrated at the inner side of the knee between the tendons of the sartorius and gracilis.

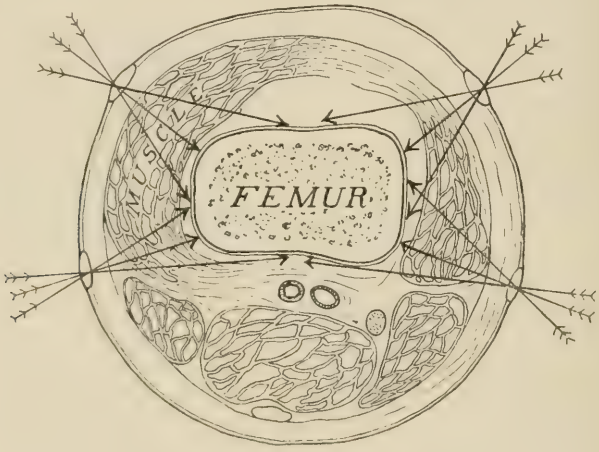


FIG. 89.—ANESTHETIZING BONE.
Injection about femur for supracondyloid osteotomy. (*Braun.*)

For operating upon the toes for ingrowing nails, the injections should be made with novocain No. 2 or 3 around the base of the phalanx.

Amputations of the leg may be done without pain after endoneural injections of the crural nerve below Poupart's ligament and of the sciatic nerve just below the gluteal fold. These particular injections give anesthesia only below the knee. But mass infiltration, from the periosteum to the skin, may be done at any place, and amputation or resection practised. When this is done the large nerve trunks should be injected as they are exposed in the course of the operation.

Disarticulations of the hip-joint were done by Lennander as follows:— Under local anesthesia the common iliac artery was exposed and temporarily clamped with rubber-covered forceps. The crural nerve and other branches of the lumbar plexus were then injected with cocain. The iliac vessels were then tied, and the femur disarticulated. The sciatic nerve, being then exposed, was injected with cocain, and the operation completed. Cocain is preferred to novocain when quick action is desired.

The more complicated procedures in the lower extremities are better carried out under subarachnoid lumbar anesthesia.

For *removing skin grafts* from the antero-external aspect of the thigh, diffuse infiltration of the skin may be practised, or the external cutaneous

nerve may be injected as it emerges at Poupart's ligament near the anterior superior spine.

For operations on the bone, such as osteotomy, four skin "stations" may be anesthetized and infiltration of the periosteum secured by multiple injections (Fig. 89).

For *fracture of the patella*, the anterior region of the joint should be surrounded by a ring of infiltration (Fig. 90). In sensitive patients there may be added to this an injection into the joint of 30 to 60 c.c. (1 to 2 ounces) of novocain solution No. 2 (with adrenalin). This fluid, if allowed to remain in the joint for five minutes, will anesthetize the synovial membrane.

For *operations on toes*, infiltration about the base, done through the skin on the dorsum is effective (Fig 91). By making the infiltration well back, the metatarsophalangeal joint may be operated upon.

For *tenotomy of the tendo Achilles* an infiltration is made around the line of incision (Fig. 92).

The Thorax.—The chest is easily invaded after local anesthesia. For opening the pleura the intercostal space may be infiltrated from the pleura to the skin with novocain solution No. 1. The same with the pericardium. *Rib resection* is done by infiltrating its periosteum on the outer surface. All of the soft tissues of the two adjacent intercostal spaces should be infiltrated. The rib is then exposed and the periosteum divided and elevated from the bone. Novocain solution No. 3 or cocain solution is then injected into the periosteum at the upper and lower borders of the rib in such a way as to reach the inner periosteum. Soon after this the bone may be cut and removed from the periosteum.

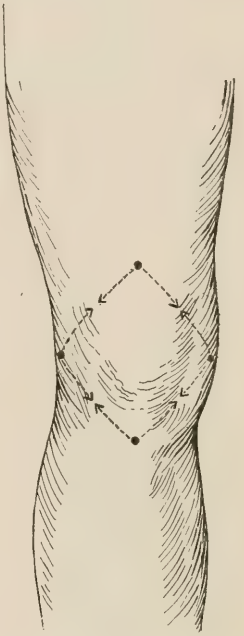


FIG. 90.—INJECTION FOR OPERATION IN REGION OF PATELLA.

If more than one rib is to be resected a perineural injection may be made around the intercostal nerves at the angles of the ribs where they lie

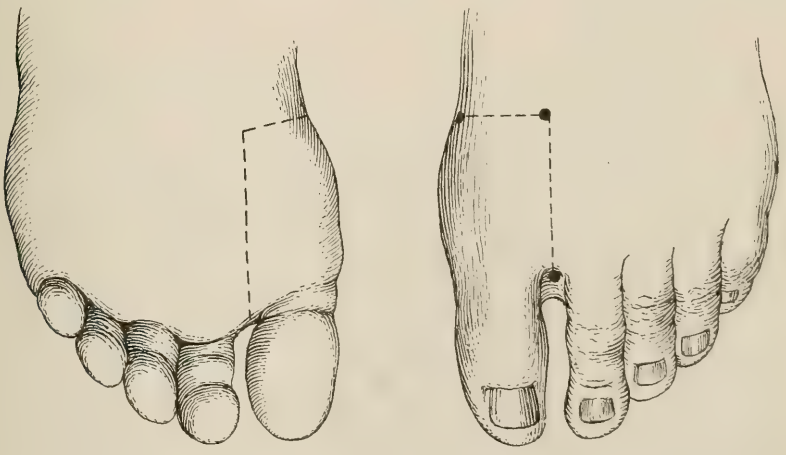


FIG. 91.—INJECTION FOR OPERATION ON GREAT TOE. (*After Allen.*)

close to the lower borders of the bones. In the groove at the lower border of the inner surface the nerve lies below the vein and artery. It may be reached with a long needle passed from behind forward parallel to the rib, the point reaching the lower border just in front of the angle. No. 4 novocain solution is best. The skin must be anesthetized by subcutaneous injections. For larger resections the lower border of the ribs may be exposed by incision, and the nerves injected.

For *thoracoplasty*, injecting 1 or 2 c.c. (15 or 30 minims) of solution at the angle of the rib and then 5 or 8 c.c. (⅙ to ¼ ounce) along the course of each nerve, using novocain No. 2, a very effective anesthesia is secured. By making an incision in the axillary line, a long needle may be passed back along the lower margin of the ribs and the injections made in this way if desired.

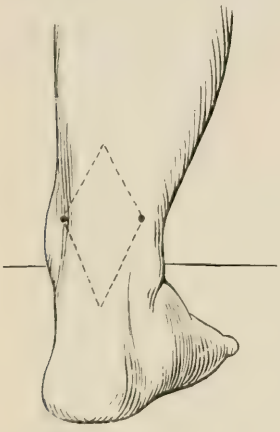


FIG. 92.—INJECTION FOR TENOTOMY OF TENDO ACHILLIS. (*Braun.*)

The *breasts* may be operated upon by infiltrating the line of incision.

For *amputation of the breast for cancer*, morphin and scopolamin may be given for its general effect. The brachial plexus should be injected (see page 892). The skin about the point of infection should be widely infiltrated. Paravertebral anesthesia is then secured by injecting about the dorsal nerves from the first to the ninth with 1 per cent. novocain solution. These injections are made at points 3.5 cm. from the median line at the lower border of the costovertebral joints. When the needle reaches the bone it is directed below the bone, forward and inward about 2 cm. further. This should be close to the dorsal nerve, where 5 c.c. of a 2 per cent. novocain solution are injected at each nerve. To complete the anesthetization, a line of infiltration with 0.5 per cent. novocain is made along the clavicle from the scapula to the sternum and thence down along the lateral border of the sternum. From 75 to 100 c.c. of solution are required for this line. With this anesthesia the breast, pectoral muscles and axilla may be dissected. In some cases an injection of the line below the line of the breast may be required.

The Abdominal Wall.—The abdominal wall derives its cutaneous nerve supply from the perforating nerves, the areas of adjoining sensory nerves overlapping one another. The parietal peritoneum is innervated by the nearest intercostal, lumbar, and sacral nerves. The phrenic nerve supplies sensation to the entire pleural surface of the diaphragm and the peritoneal surface, excepting at the rim where both the pleural and peritoneal surfaces receive sensory branches from the fifth to the twelfth intercostal nerves (M. Ramström: "Untersuchungen über die Nerven des Diaphragma," Meckel's and Bonnet's Anatomische Heften, No. 92, Bd. xxx, 1906). The main nerves of the anterior abdominal wall lie between the transversalis and the internal oblique muscles. Laterally between the ribs the perforating nerves come off, each containing cutaneous branches. There are anastomoses and overlapping of the terminations of all of these nerves. They pass back to the subserous tissues. The peritoneal nerves pass inward toward the linea alba, where they turn both upward and downward. The peritoneum of the epigastrium is supplied by the sixth to the eighth; the region just above the navel by the tenth; the area just below the navel by the tenth and eleventh, and below this by the eleventh and twelfth intercostal nerves.

For median *abdominal section*, novocain solution No. 1 is injected into the posterior part of the rectus, then beneath the anterior sheath of the muscle, and then a subcutaneous line is injected. The subcutaneous injection should be in two layers, one close to the aponeurosis and another just under the skin. At the end of half an hour the incision is made and the rectus is retracted outward. Before opening the posterior sheath of the rectus, injections should be made through it into the space between the peritoneum and the posterior layer of deep fascia. The subserous space should be well injected with (1:400) novocain solution. Or if the aponeurosis is found sufficiently anesthetic, it may be opened and the injections made directly through the wound along either side behind the fascia. It is not necessary to infiltrate the skin as the cutaneous nerves are paralyzed by the deeper injections.

H. Braun infiltrated rather widely on either side of the median line (Fig. 93). This is perhaps not necessary except when strong retraction is to be used.

In making oblique lateral incisions, the main nerve trunks which lie on the external surface of the transversalis, should be anesthetized by a liberal infiltration of novocain No. 1 or 2 between the transversalis and the internal oblique muscles. These injections should be made external, or proximally, to the place of incision. In addition to this the line of incision should be injected with solution No. 1. Attempts should not be made to inject the peritoneum or the subserosa as the abdomen may be entered and bowel punctured with the needle.

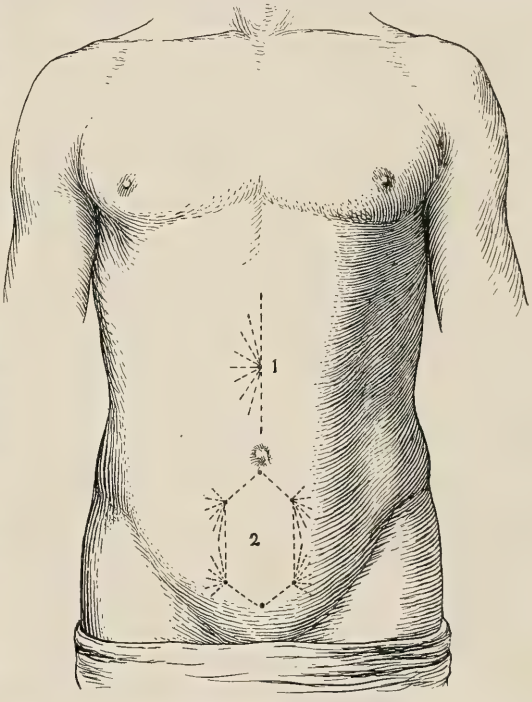


FIG. 93.—ANESTHETIZATION FOR ABDOMINAL INCISION. 1, Allen's method; 2, Braun's method.

After injections have been made between the transversalis and internal oblique, the external oblique should be injected with solution No. 1 along the course of the intended incision. Finally, the skin should be anesthetized by subcutaneous injections in the line of the incision. After the expiration of half an hour the incision may be made. If it is found that the parietal peritoneum is sensitive, injections may be made external to the peritoneum about the wound.

As traction upon the mesentery and adhesions is painful most abdominal operations can not be done under local anesthesia alone. The following are operations which may be done alone with local anesthesia: exploratory abdominal sections, operations for ascites, for tuberculous peritonitis, gastrostomies, cholecystostomies if the gall-bladder is easily accessible, enterostomies,

operations for fistula of stomach and intestines, simple removal of the appendix, volvulus, simple subserous myomata of the uterus, pedunculated ovarian tumors, other tumors whose location is known, hydatid cysts of the liver, and encapsulated exudates. In many operations a little ether narcosis may be added. *Gastro-enterostomy* may be done with local anesthesia if the operation can be carried out without making traction on the peritoneum of the posterior abdominal wall. The mesocolon requires injection.

All *gall-bladder* operations may be done very satisfactorily under local anesthesia if the operation is confined to the fundus and does not involve traction on the ducts.

For *appendicitis*, done through the muscle-splitting right iliac route, a very satisfactory result is secured by first simply making an endermal injection and then a subcutaneous injection along the line of incision. A 1 per cent. novocain solution to which are added 1.3 c.c. (20 minims) of adrenalin 1 : 1000) solution to every 30 c.c. (1 ounce) are used for the skin. After a few minutes the incision may be made down to the deep fascia. A 0.5 per cent. novocain solution is then injected under the aponeurosis of the external oblique, which after a few minutes may be divided. The fibres of the muscle are separated, and the internal oblique muscle is injected in the line of separation. After a few minutes its fibers may be separated. Solution is then injected between the transversalis fascia and the peritoneum. After a few minutes this fascia and the peritoneum may be divided without pain. The cecum is exposed and the mesocecum and mesoappendix injected. The appendix may then be removed, and the wound closed.

Inguinal hernia may be operated upon by anesthetizing the iliohypogastric, ilioinguinal, and genitocrural nerves. The position of these nerves is not constant. In some cases the two latter nerves are found united to form the external spermatic nerve. The iliohypogastric is a good sized trunk which is found at the outer upper end of the incisior, lying between the internal oblique muscle and the aponeurosis of the external oblique. It becomes subcutaneous just above and to the outer side of the external abdominal ring, and supplies the skin of this region. The external spermatic emerges from the ring with the spermatic cord. (See Hernia, Vol. III.)

Novocain solution No. 1 is first injected along the line of the intended incision between the aponeuroses of the external and internal oblique to reach the nerve trunks lying in this space. A subcutaneous injection is then made in the same line. After half an hour the operation may be done. Complete anesthesia will be found down to the cord. If the cord is found sensitive, nerve filaments should be looked for and each one injected with solution No. 2. If the sac is found sensitive it should be picked up and injections made in the subserosa about it. If the region of the pubic spine is sensitive because of innervation through the twelfth intercostal passing down to the insertion of the rectus muscle, the periosteum in that region should be injected. The external spermatic nerve should not be cut.

Femoral hernia is injected locally along the line of incision. The sac is then exposed, and the subserous tissues all around the neck of the sac injected. If desired the nerve trunks may be sought. This is done by incising above Poupart's ligament, making a small opening in the aponeurosis of the external oblique, and injecting solution No. 2 into the ilioinguinal and genitocrural nerves. General infiltration is the more satisfactory.

Umbilical and ventral hernias are anesthetized the same as the abdominal wall. The subserosa is injected above and at the sides of the hernia. The

tumor should be surrounded by a ring of infiltration in the healthy skin beyond. In the median line, the sac is opened and with the finger in the abdomen as a guide injections are made into the subserosa all around the hernia.

Genito-urinary Organs.—Suprapubic cystotomy is easily done under local anesthesia. The skin is first injected in the line of incision. Then solution No. 1 or 2 is injected behind the linea alba between the peritoneum and the posterior surface of the symphysis. Injections are made along both the posterior and anterior surface of the linea alba, and in the superficial and deep parts of the subcutaneous connective tissue. In the case of a healthy bladder nothing further is required. If the bladder is inflamed or sensitive the least motion, such as caused by incising or suturing, will cause pain referred to the urethra or perineum, and the interior of the bladder should have been anesthetized.

The interior of the bladder is rendered insensitive for such operations as crushing a stone, injecting silver nitrate, or incising and suturing, by filling it slowly with 150 c.c. (5 ounces) of a $\frac{1}{10}$ per cent solution of cocain at body temperature, to which have been added 1.7 c.c. (25 drops) of 1: 1000 adrenalin solution. The injection is effective in fifteen to thirty minutes. Anesthetization of a painful bladder is facilitated by inserting into the rectum a suppository containing 0.01 or 0.015 Gm. ($\frac{1}{6}$ or $\frac{1}{4}$ grain) of morphin and 0.03 Gm. ($\frac{1}{2}$ grain) of extract of belladonna. If the bladder contracts, it should be allowed to force out the solution, after which the solution is again allowed to run back. When bladder contractions cease the operator may know that anesthesia has been secured. This does not always succeed. Subarachnoid anesthesia i tshe only certain local method of destroying bladder sensitiveness.

Suprapubic prostatectomy may be preceded by a suppository containing 0.6 Gm. (10 grains) of anesthesin to anesthetize the rectum. An hypodermic injection of 0.01 Gm. ($\frac{1}{6}$ grain) of morphin and 0.0004 Gm. ($\frac{1}{150}$ grain) of scopolamin is given. These should be given one hour before operation. The bladder is opened by local anesthesia. With a long needle injections of 0.5 per cent. novocain solution with adrenalin are made with the view of infiltrating as much as the under surface of the prostate as possible at the periphery of the gland. To accomplish this several punctures must be made through the mucous membrane.

The *penis and urethra* are very sensitive especially the integument, prepuce, and urethra. The cavernous tissues are not sensitive. To anesthetize the urethra a catheter is passed as far as the sphincter of the bladder and from 5 to 8 c.c. (75 to 120 minims) of No. 4 novocain solution injected. The catheter is removed and the meatus kept closed for ten or fifteen minutes. No oil or ointment should have been used in the urethra. If there is a tight stricture the solution in larger amount may be injected under pressure with a syringe without the use of a catheter, the solution containing 2 drops of adrenalin (1 : 1000) to every cubic centimeter. After keeping the urethra closed for fifteen minutes to retain the solution a catheter may be passed through the stricture and the deeper part of the urethra anesthetized; or if the fluid is retained under enough pressure it will pass through the stricture.

For *perineal operations*, to the above procedure is added injection with novocain solution No. 2 of the tissues between the rectum, the bulb, the membranous urethra, and the prostate. This may be controlled by the finger in the rectum. Then injections are made at the sides of the corpora cavernosa, are lastly in the subcutaneous tissue. Under this anesthesia any operation on the deep urethra may be done.

The pendulous portion of the penis is anesthetized by perineural injections of solution No. 2 or 3 around each dorsal nerve of the penis at the point where it emerges through the suspensory ligament. A circular injection is also made in the tunica albuginea and in the subcutaneous tissue at the root of the penis. If the urethra is to be involved in the operation an injection should be made with a fine needle in the sulcus between the spongy body and the corpora cavernosa.

For *circumcision*, the above anesthesia may be used or local infiltration of the prepuce in the lines of incision. For *amputation of the penis*, the above should be combined with anesthetization of the urethra. For *meatotomy* a 4 per cent. solution is applied on a pledget of gauze just within the meatus; and after a few minutes novocain solution injected into the substance of the glans through the anesthetized mucosa.

The *scrotum and testes* are anesthetized by injecting novocain solution No. 2 or 3 around the spermatic cord. Then No. 1 is injected around the base of the scrotum into the subcutaneous tissue, into the connective tissue of the symphysis, and the muscles of the perineum. Especial pains should be taken with the injections in the region of the external ring. The septum must be injected. Either the whole scrotum or only one side may be injected. Operations such as for hydrocele, castration, or varicocele may be done.

The *Anus and Rectum*.—These parts are easily susceptible of local anesthetization. The skin around the anus is injected, and with the finger in the rectum as a control the whole region about the lower rectum may be anesthetized. Fistula, hemorrhoids, and prolapsus may be thus operated upon.

Female Generative Organs.—*The uterus* may be anesthetized by infiltrating the broad ligament with No. 1 novocain solution by means of a long, blunt needle passed through the lateral fornices of the vagina and kept close to the uterus. When this is combined with injection into the uterine cavity of a $\frac{1}{10}$ per cent. cocain solution, dilatation, curettage, and other operations on the uterus may be done. The injection of 0.02 to 0.04 Gm. ($\frac{1}{3}$ to $\frac{5}{8}$ grain) of cocain in a 1 or 2 per cent. solution gives twenty-five minutes of anesthesia for curettage. The injection into the substance of the cervix in four places of 1 or 2 c.c. of anesthetic solution allows dilatation and other operations without resistance or pain.

Cesarean section is done with simple anesthetization of the abdominal wall.

Conclusions Concerning Local Infiltration Anesthesia.—This method is safe when non-toxic amounts of anesthetic are used. The best are novocain in 0.25 to 0.5 per cent. in normal salt solution with adrenalin. As much as 150 to 300 c.c. (5 to 10 ounces) of these solutions may be used, provided that not more than 0.5 Gm. (8 grains) of the drug are injected. The adrenalin is especially useful in fixing the drug in the tissues and thus prolonging anesthesia. The adrenalin should not be used in concentrated solution as it is apt to cause local necrosis of tissue. The 1 : 1000 strength should be used, of which 1 drop should be added to every 100 drops of novocain solution. It is applicable to a large range of cases, and may be employed where general anesthesia is not desired.

The Anesthetic Injection of Nerve Roots.—*The trunk* may be anesthetized in any of its parts or areas by anesthetizing the *spinal nerves at their exit* from the spine (*paravertebral anesthesia*). The injection is made in the angle between the rib and the transverse process of the dorsal vertebræ. The needle is inserted close to the lower border of the rib about 3.5 cm. ($1\frac{3}{8}$ inches) from

the median line. At a distance of 4 or 5 cm. (1½ or 2 inches) from the skin to needle reaches the rib. The lower edge of the rib is felt for with the needle, and when it slides under the lower edge it is directed slightly toward the median line, and pushed on until the point of the needle has passed the lower border of the rib. The fluid is injected in two or three directions in this region. To inject the region of more than one nerve, about 3 cm. (1¼ inches) will be found to be the distance between them, and having located the lower border of one rib the adjacent spaces are easily found. After an injection has been made the needle may be left in, and a second needle used for the next injection. By leaving in the last needle it serves as a guide. Some surgeons inject 5 c.c. (1¼ drams) of 1 per cent. novocain at each segment of the spine. The lower dorsal injections may be made at the level of the tips of the spinous processes as a guide. The lower margin of the transverse process may be sought with the needle, and the point pushed in ½ to 1 cm. (3/16 to ⅜ inch) further, the point being directed slightly toward the median line. It is possible to strike the nerve. This is manifested by pain radiating forward.

By injecting 10 c.c. (⅓ ounce) of ½ of 1 per cent. novocain solution with adrenalin respectively at the eighth, ninth, tenth, eleventh, and twelfth dorsal vertebræ, and the first and second lumbar, such operations as *nephrectomy* may be proceeded with in fifteen minutes. Traction upon the peritoneum causes pain, which may be met with a little ether inhalation.

The average interval between the transverse processes in the dorsal region is about 13 mm. (½ inch). The distance from the middle of one space to the middle of the next is 2.5 cm. (1 inch).

In the lumbar region the space is from 13 to 20 mm. (½ to ¾ inch). The distance from the middle of one space to the middle of the next is 3 cm. (1¼ inches). It is somewhat easier to make the puncture in the lumbar than in the dorsal region. To reach the lumbar nerves, the spine of the first is located, and a point on the skin from 3 to 3½ cm. (1¼ to 1⅓ inches) laterally is anesthetized. Here the needle is passed horizontally forward for 4 or 5 cm. (1½ or 2 inches) until it meets the transverse process. The upper border of the process is then found with the needle point, and the needle passed upward and inward ½ to 1 cm. (3/16 to ⅜ inch) further and the injection made with 5 c.c. of a 1 per cent. novocain-adrenalin solution. The first, second, and third lumbar nerves are reached at intervals of 3½ to 4 cm. (1⅓ to 1½ inches).

In the cervical region, a line on either side of the spinous processes is anesthetized, and a long needle is passed forward until it meets the transverse process. The needle is then advanced under the process 1 to 1½ cm. (⅜ to ⅝ inch) further, and the injection made.

This method of reaching the vertebral nerves is used in making injections to relieve the pains of locomotor ataxia.

The nerves may be reached for injections for local anesthesia by the same route as for injections for neuralgia. Practically every operation in surgery has been done by this method (see Special Nerves, page 865). For references to regional nerve trunks see Jour. Am. Med. Assoc., vol. lxi, No. 11, p. 842—"Local Anesthesia:" J. F. Mitchell.

The *pudic nerve*, which supplies the scrotum, perineal and anal regions, and external female genitals, may be anesthetized by inserting the needle at the middle of the inward slope of the tuberosity of the ischium in the direction of the sacrosciatic foramen. A considerable amount of solution should be used. The object should not be to reach the nerve trunk as there is danger of puncturing the adjacent vessels. The injection should be thrown about the nerve between the ischiorectal fossa and the lesser sacrosciatic

foramen. The finger in the vagina or rectum locates the spine of the ischium, and guides the needle. Extraction of the fetus with forceps may be done without pain, as well as perineal and pudendal operations.

The *brachial plexus* may be reached without incision. The patient sits with the surgeon at his side. The subclavian artery is located by feeling. The needle is inserted above the upper margin of the clavicle at the outer part of its middle third to avoid the vessels. The object is to reach the plexus just above the point at which it is crossed by the omohyoid muscle and the transversalis coli artery. The point of the needle should be directed toward the tip of the spinous process of the second or third dorsal vertebra. Solution injected as soon as one of the trunks is touched causes anesthesia.

The plexus lies to its outer side, the vein to the inner side. The plexus is in contact with the artery. The needle is best passed before it is connected to the syringe. It passes backward, downward and inward. The plexus lies just under the deep fascia as it crosses over the first rib. The needle must penetrate from 2 to 4 cm. (¾ to 1½ inches). When the plexus is reached a radiating pain is felt by the patient in the distribution of the radial or median nerve in the hand. The syringe is then attached and the injection made.

If a fine needle has been used, and the vessel is punctured, the needle should be withdrawn slightly, and usually no leakage will take place. The needle should then be passed a little further externally. An injection of 20 c.c. of a 2 per cent. solution of novocain should be distributed in and about the plexus. If anesthesia does not come on in fifteen minutes, another injection had better be made. The anesthesia lasts from one-half hour to three hours. Complete muscular relaxation accompanies the anesthesia.

For *amputation of the leg*, the femoral, tibial, and obturator nerves may be blocked. The patient lies on the abdomen, and the needle is inserted vertically at a point 2 cm. ($1\frac{3}{16}$ inch) external to the tuberosity of the ischium. About 30 c.c. (1 ounce) of anesthetic solution is injected. The needle is then withdrawn half way and reinserted outward, and 10 c.c. (⅓ ounce) of anesthetic injected. The needle is then removed and inserted 2 cm. ($1\frac{3}{16}$ inch) internal to the great trochanter, and passed forward and slightly inward and an injection made. The point of the needle is then moved and injections made throughout the whole area between these two points.

Conclusions Concerning Nerve Blocking.—This method is effective and fairly safe, excepting when such structures as the gasserian ganglion, the great sciatic and the brachial plexus are injected. This requires skill and can be regarded as neither safe nor simple anesthetization. Injecting the large nerve trunks is rarely to be preferred to the more simple methods of anesthesia. It is not always dependable, and often must be supplemented by general anesthesia.

Cold.—Cold numbs the sensory nerves. A mixture of *ice* and common salt was once used to anesthetize the skin for operative incisions. Ice alone applied for a few minutes to a proposed line of incision will render it insensitive. I have often used ice to benumb a point for the insertion of an aspirating needle or other puncture.

The skin may be frozen by volatile substances such as *ether*. By their rapid evaporation they cause refrigeration and local numbing of sensation when sprayed on the skin in a dry moving atmosphere. *Ethyl chloride*, or a mixture of ethyl chloride and *methyl chloride*, sprayed on the skin rapidly causes superficial freezing. Ethyl chloride is put up in glass tubes containing about 30 c.c. (1 ounce). An opening at one end permits the escape of a capillary stream which is forced out by the warmth of the hand applied

to the tube. This spray when directed upon the skin in a few seconds causes redness, then pallor and then white freezing of the skin. The fluids in the superficial tissues are actually turned into ice. Incision may be made through the frozen skin without pain reaction from the skin nerves. No attempt should be made to freeze deeper than the skin, or sloughing may be expected. If only the skin is frozen for a few seconds it recovers without harm. Prolonged freezing should not be attempted. If the tissues are inflamed the pressure of the knife in making the incision will cause severe pain.

Ethyl chloride freezing is useful for making a single skin incision of any length. After making the deep injections of local anesthetic the time required for the superficial injections may be saved by anesthetizing the skin with ethyl chloride. It is useful for lengthening the skin incision in the course of an operation under local anesthesia. It may be used to numb the skin for suturing.

The process of freezing is attended with some pain. While frozen the nerve terminals are insensitive. Swelling of the blood-vessels, redness of the part, and smarting pain follow the thawing process, and often last for several hours.

Local Anemia.—The ancients attempted to render parts insensitive by compressing the main blood-vessels. It is possible that the anesthesia thus produced was due more to pressure upon nerve trunks than upon vessels. If a rubber bandage is applied from the distal part of an extremity toward the trunk so that the blood is squeezed out of the part and excluded, numbness supervenes. This is partly due to anemia of the nerves, but it is also partly due to the pressure of the bandage upon nerve trunks, and the relative importance of the two can not be computed. It is known that anemia of a part, caused by the occlusion of the nutrient arteries, is associated with anesthesia which supervenes before gangrene appears. This principle of anemia anesthesia may sometimes be utilized in surgery.

It should be remembered that cyanosis, such as is produced by placing a constriction at the base of a member, not only does not cause anesthesia but actually renders the parts more sensitive to pain. Anesthesia under these circumstances occurs only from the pressure upon nerve trunks and when coagulation in the vessels and gangrene have taken place.

Nerve Pressure.—Pressure upon a mixed nerve causes first motor paralysis and then sensory paralysis. By making pressure on a sensory nerve a tingling and pricking sensation in the parts supplied by it is followed by anesthesia. The pressure which is great enough to cause anesthesia may in the case of larger nerves cause injury to the nerve which lasts for a long time. Smaller nerves are less important.

The lower jaw may be rendered anesthetic for the extraction of teeth and similar operations by pressing for a few minutes upon the inferior dental nerve at the point of entrance into the foramen on the inner aspect of the inferior maxilla. This pressure may be applied with a blunt instrument or with the fingers. Numbing of sensation for extracting teeth may be secured by making firm pressure on both sides of the alveolar process.

SPINAL ANESTHESIA

Spinal analgesia is accomplished by the injection of analgesic substances into the subarachnoid space, between the continuation of the spinal cord and the dura mater lining the spinal canal. It will be remembered that the cord ends at the second lumbar vertebra, and is continued downward as a bundle of lumbar and sacral nerves. From the second lumbar vertebra down to

the end of the dural sac at the third sacral vertebra, the subarachnoid sac is not divided by a septum as above. At the lower end of the cord, at the conus medullaris, the nerve roots are arranged in lateral bundles. Between the two sides is a space 2 to 5 mm. wide at the level of the second lumbar vertebra. This shallow space between the dura and arachnoid contains the cerebrospinal fluid and communicates with the ventricles of the brain.

The **cerebrospinal fluid** is a clear watery substance, having a specific gravity of 1.003 or 1.004, and containing serum salts and a very small amount of albumin. It exists to the amount of 50 to 150 c.c. (1⅔ to 5 ounces). The pressure in the subarachnoid space in the lumbar region is equal to 60 to 100 mm. of water. In the sitting position it gravitates to fill the lower space, but in the recumbent position if the pelvis is elevated none can be drawn from the lumbar region. In response to the laws of fluids, it moves readily from the lumbar region to the base of the brain by the variations of elevation of the parts.

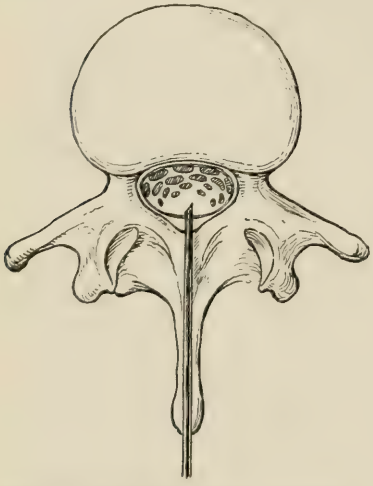


Fig. 94.—Showing Point of Needle Lying in Subarachnoid Space.

It is important that a concentrated dose of poisonous anesthetic should not be carried to the vital centres. This may be regulated by (1) the character of the drug used; (2) the specific gravity of the substance; (3) its mixture with other materials to regulate its specific gravity; and (4) the position of the patient. By mixing the drug with a substance of different viscosity, such as gum arabic, or glucose, the mixing with the cerebrospinal fluid is delayed and the position of the drug may be regulated.

By regulating the density of the injected fluid, it may be kept localized in the lower part of the sac, its diffusion delayed, and consequently a smaller amount may be used with better effect than when the drug is rapidly dissolved throughout the cerebrospinal tract.

If a hollow needle is used to tap this space (Fig. 94), and a small amount of anesthetic agent injected in the place of the cerebrospinal fluid withdrawn, the patient becomes insensitive to pain from the point of injection downward. This method is of use where general anesthesia is contraindicated, where shock is feared, or where the consciousness of the patient is desired. It has been much employed also in obstetrics. In Cesarean sections for eclampsia it lowers blood-pressure and seems to act well; also in the confinement of women with pulmonary tuberculosis and certain diseases of the heart. It is used in children as well as adults.

It may be employed for any operation below the umbilicus. Some surgeons regard it as the anesthetic of choice for operations on the kidneys. Perhaps its best field is in chronic intestinal diseases and in operations below the umbilicus.

Of the drugs used **cocain** was found to be dangerous and has been largely supplanted by less toxic substances. **Novocain, tropocain,** and **stovain** are most used. Most surgeons use an isotonic solution of one of these latter drugs. Five per cent. tropocain fulfills this requirement. By mak-

ing a solution of 5 parts stovain, 5 parts glucose, and 90 parts distilled water, a fluid is produced which is heavier than the cerebrospinal fluid, sinks to the bottom when injected, and diffuses slowly. A still better preparation is stovain 4 parts, lactic acid 2 parts, glucose 5 parts, and distilled water to make 100 parts. The lactic acid is added because the cerebrospinal fluid precipitates the drug unless it is rendered acid.

A 5 per cent. tropocain solution is heavier than cerebrospinal fluid, and also sinks before it diffuses. The success which has attended the use of this solution is probably due to the fact that its specific gravity is 1.0106, while that of the cerebrospinal fluid is 1.007.

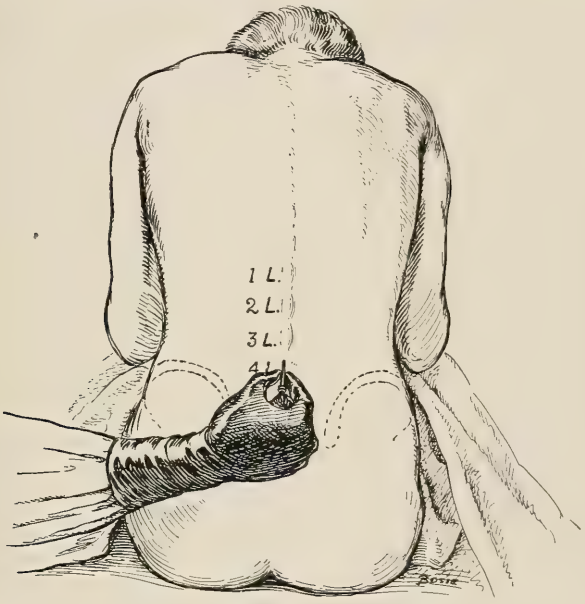


FIG. 95.—LUMBAR PUNCTURE OF SUBARACHNOID SPACE IN SITTING POSITION.

A 5 per cent. stovain solution has a specific gravity of 1.0064. It is lighter than cerebrospinal fluid and consequently seeks the upper levels and gives uncertain results. Adrenalin is not used in spinal injections.

The 5 per cent. tropocain solution may be recommended for most operations. The dose is 0.03 to 0.06 Gm. (½ to 1 grain). For operations on the perineum and external genitals 0.03 to 0.05 Gm. (½ to ¾ grain) of the drug may be used; for operations on the legs and thighs, 0.05 Gm. (¾ grain); and for the abdomen 0.07 Gm. (1⅙ grains).

The patient may be given a preliminary injection of morphin and atropin, or morphin and scopolamin, one or two hours before the operation. To diminish psychic shock it is best to inject 0.01 Gm. (⅙ grain) of morphin two hours before the operation, and the same again one hour before operation.

The **technic** of spinal anesthesia requires experience for its best application. A sterilizable syringe holding 2 c.c. (30 minims) is commonly used (Fig. 36). Larger sizes are preferred by some surgeons, but as it is best to have the solution ready mixed, the larger syringes are not necessary. A needle provided with a stilette or trocar is best. The needle should be about three times the size of the ordinary hypodermic needle. For ordinary use a

needle 6 or 7 cm. ($2\frac{3}{8}$ to $2\frac{3}{4}$ inches) long is employed. A needle 8 or 10 cm. (3 to 4 inches) long is required for heavy persons. The needle is detached from the syringe, and the stilette introduced before it is used.

The end of the needle should not have too sharp a point as the arachnoid space is shallow and the opening of the needle must be near the end. The instruments should have been boiled in distilled water or washed in distilled water after boiling in order to remove alkalies which might interfere with the action of the anesthetic drug.

FIG. 96.—LUMBAR PUNCTURE OF SUBARACHNOID SPACE WITH PATIENT LYING ON TABLE.

It is best that the patient should sit with his legs over the side of the table, his feet resting on a chair, the body bent forward so as to flex the lumbar spine, and with a nurse standing in front (Fig. 95). This position makes prominent the lumbar spinous processes, widens the spaces between them, and prevents the anesthetic rising to the higher nerves. It is necessary that the patient should be kept in the sitting position only about three minutes, for by this time the anesthetic has become fixed in the substance of the nerves. The patient should be *slowly* placed in the recumbent position.

If the patient is weak or syncopic, he may lie on the side with the knees drawn toward the chest, and the head and shoulders slightly elevated (Fig. 96). The best place for the puncture is between the second and third

or third and fourth lumbar vertebræ. A line drawn between the highest points of the iliac crests passes through the spine of the fourth lumbar vertebra (Fig. 97). The needle should be inserted in the first interspace above this line, directly in the middle line, and passed forward and in a slightly upward direction. Some prefer to insert the needle a little to the side and point it slightly upward and inward. At this point the distance between the skin and the subdural space is about 4 to 6 cm. In heavy muscular persons it may be 7 or 8 cm., and in fat persons as much as 10 cm. (Fig. 98).

This operation should be done with deliberation and the greatest aseptic care, lest infective material be carried into the spinal canal. The patient

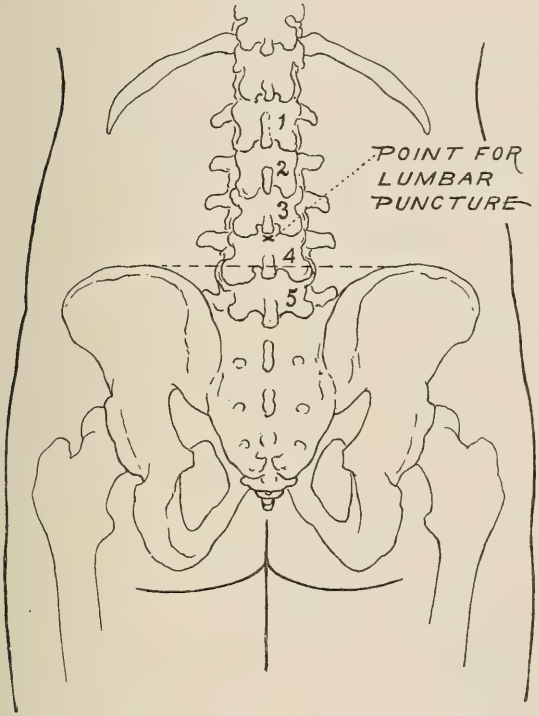


FIG. 97.—SHOWING POINT FOR LUMBAR PUNCTURE.

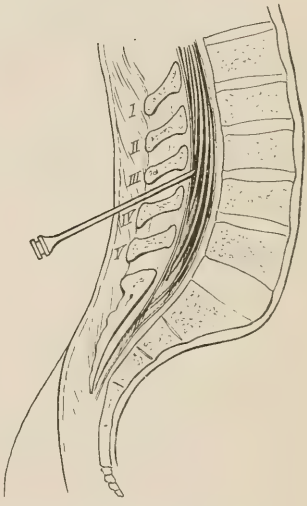


FIG. 98.—SHOWING NEEDLE PASSING BETWEEN SPINOUS PROCESSES OF THIRD AND FOURTH LUMBAR VERTEBRÆ TO ENTER SUBARACHNOID SPACE.

may be spared the pain of the prick by anesthetizing the skin with the chloride of ethyl spray. In order to avoid carrying in the skin bacteria on the end of the needle the skin should be sterilized with iodin. To prevent occlusion of the needle with epithelium, the skin may first be punctured with a sharp-pointed knife. Through this wound the surgeon introduces the needle.

When the trunk is strongly flexed the space between the vertebræ posteriorly is about equal to the diameter of an ordinary lead pencil (8 mm.). The resistance of the intervertebral ligaments is felt, and then a little farther the sensation of non-resistance is imparted by the needle to the fingers. As soon as the ligaments have been pierced the stilette may be withdrawn and the needle pushed forward. Care should be taken that the needle does not traverse the whole diameter of the spinal canal and impinge upon the back of

the body of the vertebra. The object is to tap the space in its posterior part. As soon as the needle passes through the dura and arachnoid, its point lies in the subarachnoid space, and cerebrospinal fluid will be observed flowing in drops from the needle (Fig. 51*b*). An amount of the fluid about equal to the amount of solution which it is intended to inject should be allowed to escape. If the fluid does not flow out it means that the space has not been reached or that the needle is blocked. The injection should not be made until the drops of clear cerebrospinal fluid appear.

In introducing the needle, if it seems to strike against a bone, it should be withdrawn and its direction slightly changed. If the cerebrospinal fluid is not clear disease or injury of the meninges exists and no injection should be made. If blood flows from the needle its position should be changed. If the needle is apparently in the spinal canal but the fluid does not flow forth, the stilette may be pushed through the needle to remove any obstructing material. If the fluid still does not appear, it may be assumed that the needle has entered the nerves of the cauda equina and should the injection be made, an uncertain and unequal anesthesia will be secured. It may be laid down as a rule that if clear cerebrospinal fluid is not seen flowing freely the injection should be abandoned.

The cisterna terminalis of the subarachnoid space having been reached 2 or 3 c.c. (30 or 45 minims) of fluid are allowed to flow out through the needle into a measuring glass. The syringe, containing the proper dose of anesthetic, should be attached to the needle, and the injection of anesthetic solution made. One or 2 c.c. (30 minims) of solution containing 5 per cent. stovain and 5 per cent. glucose may be used. One cubic centimeter of this solution, containing 0.05 Gm. (¾ grain) of stovain produces analgesia to the level of the navel in from two to ten minutes, which lasts from fifty to sixty-five minutes. For longer operations 1.2 c.c. of this solution, containing 0.06 Gm. (1 grain) of stovain, may be used. Instead of the above, tropococain may be used in 5 per cent. solution, either with or without the addition of glucose.

The heavier solution gravitates to the most dependent part of the spinal canal. If the patient is lying on the side, analgesia will be produced on that side. By keeping the shoulders slightly elevated the action of the drug is kept from the upper part of the body. By utilizing this hydrostatic principle the area affected may be controlled. Usually the patient feels numbness in the feet two minutes after the injection. This numbness gradually ascends till it reaches the upper limit of the nerve supply affected.

While operating, a screen should be so placed that the patient does not see the operation, blood, or instruments. A nurse or doctor should sit by his head to apply such psychic influences as seem indicated. For operations upon the abdomen or perineum stovain and tropacocain cause muscular relaxation as well as analgesia. There is loss of pain sensation before heat and tactile sensation have disappeared.

In the early part of the operation the patient often becomes pale, perspiration appears, and nausea and vomiting may follow. These phenomena pass off after a few minutes. There is lowering of blood-pressure and slowing of the pulse-rate. If the anesthetic travels to the ribs there may be a sense of thoracic oppression, difficulty of breathing, air hunger, and inability to cough. Many of these phenomena may have a psychic basis.

In a considerable proportion of cases some of these untoward symptoms appear. Nausea, vomiting, cardiac or respiratory depression, incontinence of the bowel or bladder, and headache are often observed. Subsequent headache and nervous disturbances may occur. The temperature is usually elevated to 38°C. (100°F.) for two days. Paralysis of ocular muscles,

paraplegia and other evidences of faulty technic sometimes appear. The danger of infecting the spinal sac is never to be lost sight of. Should the respiratory centres become paralyzed tracheal insufflation should be practised at once.

A number of fatalities are attributable to spinal analgesia. The important points to be borne in mind are to confine the agent to the lower part of the cord away from the vital centres, to use a minimum amount of anesthetic, to throw in an amount of fluid not greater than that which is removed, to guard the patient from psychic depression, and to be ready with restorative measures.

High spinal anesthesia was practised by Jonnesco, who made the injection at a level appropriate to the region to be operated upon. In order to obviate the danger of depression of the nerve centres he added strychnia as a central stimulant. The desired quantity of stovain is sterilized in a glass bottle with a rubber stopper in the autoclave. Neutral strychnin sulphate, 0.05 Gm. (¾ grain), is dissolved in 100 c.c. (3⅓ ounces) of sterilized water in a sterile bottle. The drug does not need to be sterilized. One c.c. of this solution contains 0.0005 Gm. ($\frac{1}{130}$ grain) of strychnin. This solution is used for the upper dorsal region; a solution containing twice this amount of strychnin is used for the lower region. One c.c. of the strychnin solution is added to the stovain and shaken.

The upper puncture is made between the first and second dorsal vertebræ, the patient sitting with the chin on the chest. This gives anesthesia for the head, neck, and upper limbs. The position of the patient influences the localization. If analgesia of the head and neck is desired the patient should lie on his back; if the operation is to be on the throat, the head should be slightly raised; if the operation is to be on the face or skull the patient should lie horizontally; if on the upper extremity or thorax he should remain sitting for two or three minutes and then lie on the back with the head and neck bent forward. If the analgesia is not complete in the head or neck after two or three minutes the head should be lowered below the rest of the body for three or four minutes. Even in the hands of the most experienced this method is still to be considered dangerous and by no means to be adopted as a routine.

Spinal analgesia as a whole is to be used only when general anesthesia is contraindicated and local anesthesia ineffective.

Conclusions Concerning Spinal Anesthesia.—It is very dangerous and probably has a death rate of 1 to every 500 or 1000 cases. It is not comfortable for the patient, particularly if he is intelligent enough to realize the gravity of the procedure. It fails to give satisfactory anesthesia in about 5 or 10 per cent. of cases. The method requires especial skill and care in its application, and the drug once injected is largely beyond the control of the surgeon. It is too dangerous and difficult to be regarded as an acceptable routine measure, but should be reserved for special cases.

The injection of magnesium sulphate into the spinal canal, 1 c.c. of a 25 per cent. solution for every 10 kilos (25 pounds) of body weight, causes both sensory and muscular paralysis. The action is very slow, one or two hours elapsing before the effect is observed, and the paralysis continuing for one or two days. Saturated solution of this salt applied to the broken skin has the power of relieving pain both local and reflex.

The addition of a little *gum arabic* or *glucose* to cocain, tropococain and stovain solutions seems to prevent their absorption by the higher centres and prolongs their action (Erhardt). Salt solution injected at a temperature of 0°C. (32°F.) in amount equal to the spinal fluid withdrawn has an analgesic action (Oelsner and Kroner).

EPIDURAL SACRAL INJECTIONS

The dural sac ends at the third sacral segment. The spinal canal below this contains nerve trunks which form the sciatic and pudic nerves. These trunks may be anesthetized in the canal. The patient lies on the abdomen or the side. The lower opening of the sacral canal is sought for. It is at the sacro-coccygeal junction. The skin is anesthetized, and a long needle is inserted in the opening and pushed upward in the canal for a distance of 4 or 5 cm. (1½ or 2 inches). The solution is then injected.

Salt solution, plain water, or local anesthetic may be used, depending upon the object of the operation. In enuresis, salt solution cures half of the cases. In neuralgias of the sacral nerves salt solution is often of help. For anesthetizing the nerves this route is not wholly satisfactory.

For anesthesia for operations the best results have been had with 1 per cent. solution of novocain and 1 per cent. solution of potassium sulphate. These two solutions are mixed when ready for use, and 0.12 c.c. (2 drops) of adrenalin (1:1000) added for each 30 c.c. (1 ounce) of the solution. From 45 to 90 c.c. of the mixture are injected. In fifteen or twenty minutes the bladder, prostate and urethra should be anesthetized. With this method suprapubic and perineal prostatectomy, cystotomy, cystoscopy, urethrotomy, and rectal operations may be done. The analgesia fails in a certain proportion of cases.

PARASACRAL ANESTHESIA

Injections of the sacral nerves as they emerge from the sacral foramina is similar to paravertebral anesthesia. The patient is placed in the perineal

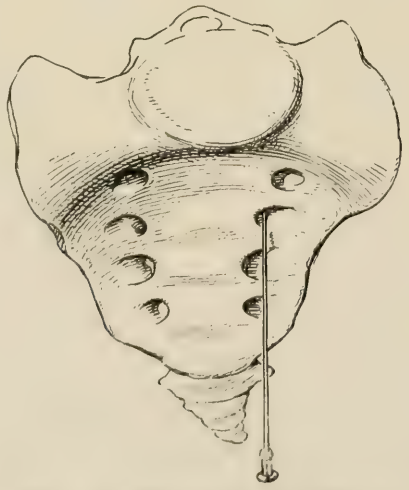


FIG. 99.—PARASACRAL ANESTHESIA.
Showing method of placing needle.

lithotomy position with the pelvis raised. The tip of the coccyx is located. A mark is made on either side of it 1½ or 2 cm. from the mid-point. A needle is introduced at this point. It is pushed directly upward toward the hollow of the sacrum until it strikes the bone. This is usually at a depth of 7 or 8 cm. (2¾ or 3⅛ inches). The needle is then at the second sacral foramen. Here 25 c.c. of a 0.5 per cent. novocain solution are injected after withdrawing the needle 1 cm. Then 35 c.c. are injected

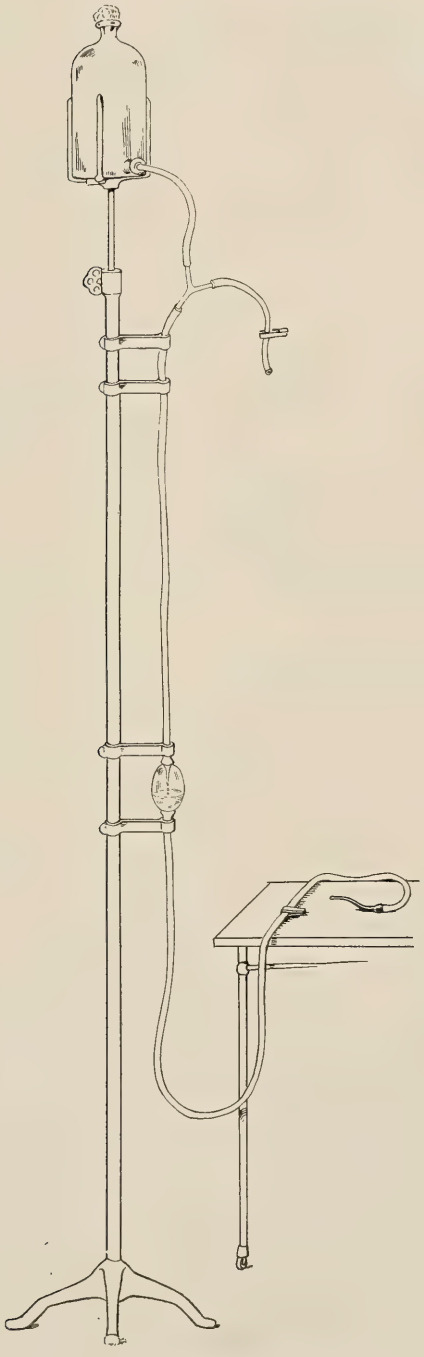


FIG. 100.—INTRAVENOUS ANESTHESIA APPARATUS. .
Showing vessel for anesthetic mixture, extra tube-connection for introducing other fluid dropper for observing flow, and point for insertion in vein.

while the needle is gradually withdrawn to the skin. This injects the third, fourth and fifth sacral nerves. The needle is then introduced at a slightly greater angle to strike the bone at a depth of 10 to 12 cm. After withdrawing it 1 cm., 20 c.c. of the solution are injected (Fig. 99). The same is repeated on the other side. The needle is then withdrawn, and 5 c.c. injected between the tip of the coccyx and the rectum. This gives anesthesia for vaginal operations. If the operation is to include the uterus and adnexa lumbar paravertebral anesthesia may be added. Prostatectomy and resection of rectum, may be done.

INTRAVENOUS GENERAL ANESTHESIA

For this form of anesthesia *ether* is usually employed (see page 114). Morphin, atropin, and scopolamin may be given before the infusion. They are not necessary. Ether is used in a 5 or 7.5 per cent. solution in normal salt solution (Ringer) at a temperature of 30°C. (86°F.). This solution is administered from a reservoir holding 1500 or 2000 c.c. (Fig. 100). Pains should be taken to see that the ether is thoroughly mixed by shaking well. The operative technic is the same as for saline infusion.

It is advisable to have two reservoirs, one for the ether solution and another for salt solution, connected by a Y-tube. The flow of one or the other should be continuous in order to prevent thrombus formation.

Ether and *paraldehyde* give good results. Paraldehyde boils at a higher temperature than ether. It may be mixed with an equal amount of ether. Five to 15 c.c. of each are dissolved in 150 c.c. of 1 per cent. sodium chloride solution in sterile distilled water. The solution may be injected at a temperature of 25°C. (77°F.) from the apparatus used in injecting salvarsan. The fluid is allowed to flow into the vein at the rate of 5 or 10 c.c. per minute. H. Noel and H. S. Souttar (Annals of Surg., vol. 57, 1913) observed that in five seconds the patient tastes paraldehyde, in ten seconds it can be detected in the breath, in twenty seconds, the patient has a sensation of floating or dizziness, in thirty seconds, consciousness begins to disappear, in forty seconds unconsciousness is complete, in sixty seconds deep unconsciousness is present, and in ninty seconds, corneal reflexes are absent and anesthesia is complete. This drug may be used in alcoholics.

Mixtures of ether with *hedonal* and with *isopral* are also employed. From 1 to 1.5 per cent. are added to the ether solution.

Hedonal is used very largely in some of the Russian clinics. The solution is allowed to flow in at the rate of 50 to 60 c.c. per minute.

Intravenous anesthesia is used in operations about the head and neck, trachea, jaws, and base of the skull. It may be used in any cases excepting in arteriosclerosis and high blood-pressure. It seems especially valuable in weak individuals.

Anesthesia by the **intravenous injection of magnesium sulphate** was first applied for the purposes of operations on man by C. H. Peck and S. J. Meltzer (Jour. Am. Med. Assoc., Oct. 14, 1916). A 6 per cent. solution of magnesium sulphate is allowed to flow slowly through a needle inserted in a vein in the arm. From 180 to 400 c.c. of this solution may be infused in patients weighing from 120 to 160 pounds, at the rate of 8 c.c. per minute, for a period of forty-five minutes. The infusion must be given thus slowly. Apparatus for intratracheal insufflation should be at hand to meet respiratory paralysis. The patient becomes unconscious and loses sensation of pain. The drug is very dangerous. Calcium chloride solution should be at hand to neutralize the toxic effect of the drug if necessary. Relaxation of the muscles follows abolition of pain sensation.

Conclusions Concerning Intravenous General Anesthesia.—This method is highly dangerous and not to be considered as a routine method. So far as the effects of the ether are concerned, they are much the same as after ether inhalation. A serious surgical operation (venous infusion) must be added to the hazard of the anesthesia. Special skill is required. It has little place in surgery, and, is to be used only in exceptional cases.

CONCLUSIONS CONCERNING ANESTHETICS AND ANESTHETIC MEASURES

For general use the open-drop-ether method is to be preferred.

For short operations in which complete anesthesia is desired, but relaxation is not necessary, nitrous oxide and oxygen should be chosen.

For operations about the face and head in which the ether or gas mask would obstruct the operative field, intrapharyngeal etherization by means of tubes passed through the nose or mouth, is the method of choice.

For operations in the thorax, requiring inflation of the lungs, intratracheal insufflation is useful.

Local infiltration anesthesia should be used in cases in which there is some objection or contraindication to general anesthesia or in which the intelligent coöperation of the patient is desired during the operation.

All the other methods of anesthesia could be dispensed with and surgery be not retarded. There are certain exceptional conditions which may now and then be met by the use of the exceptional methods, but they are very rare.

Operations Without Anesthetic.—Finally there are *operations in which no anesthetic is indicated.* These are conditions in which the pain sense is already inhibited, in which time can not be spared, in injuries to the brain and cord, toxic unconsciousness, profound depression, emergencies, and in cases in which the anesthetic would do more harm than the pain.

WOUNDS

GENERAL CONSIDERATIONS

In the treatment of wounds the most important prerequisite for success is asepsis—the removal and exclusion of bacteria. The tissues of the body are able to destroy a certain number of bacteria when introduced into a wound. This natural resisting power is variable, depending upon the number and kind of bacteria, upon the ability of the leukocytes and secretions to gain access to them, upon the amount of dead or foreign material in the wound, upon the facility of escape of ptomain-laden fluids, and upon the presence and degree of the vital complex called immunity. Every effort should be made to tax as little as possible this vital resistance of the body against infection, because of the uncertainty of the amount of resistance and of the degree of infection.

In **accidental wounds** the infection can not be controlled, excepting that cleanliness of body and environment minimizes the number of microörganisms that may be carried into such a wound. Here the surgeon is concerned with the removal of as much of the infection as is possible, with the protection of the wound against further infection, and with the maintenance or improvement of the resisting power of the patient.

In **wounds made by the surgeon,** the condition is different. Operations are preceded by preparation of the patient, of the operative area and of the environment in which the operation is to be done. It is in the attention to these details that modern surgery has made its greatest advancements and the greatest safety has been thrown about the surgical patient.

THE OPERATING ROOM

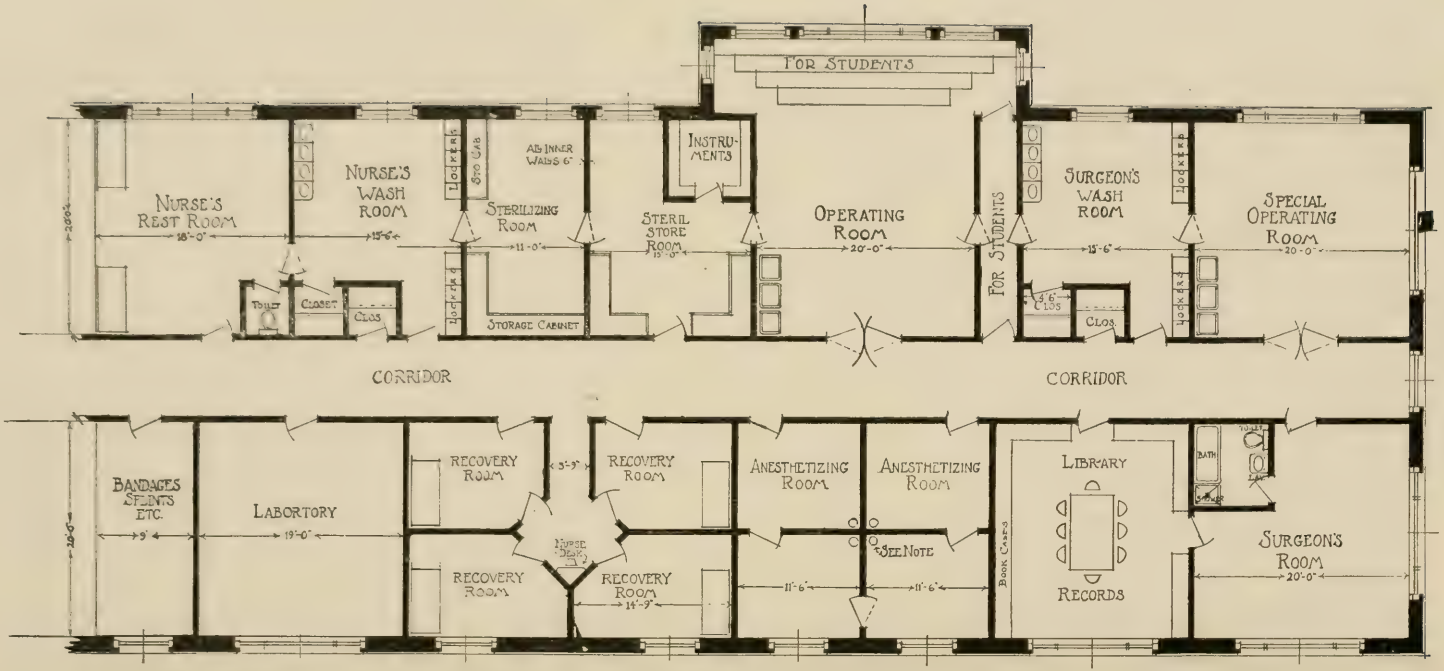
The operating room in a hospital should be situated away from the general activities of the institution. It should be most simple in architectural details, free from corners, and the walls covered with washable paint, enamel or tiling. It should be well lighted, both from the sides and roof. For artificial illumination there should not be a single central light, but, in order to avoid shadows, the light should come from several distributed sources above.

The color of the operating room is important. Up to the present it has been customary to use white for walls, ceiling and appurtenances. This is trying to the eyes, unnatural, and inartistic. The first modern variation from this, with which I am familiar was made by H. M. Sherman at St. Luke's Hospital in San Francisco. He used spinach green for the floor and wainscot up to 2 meters (6 feet) above the floor; above this the walls were of white and castor tiling; and the ceiling was painted bright buff. Operating gowns, suits, and protective sheets were of black. The preference should be for sage green floor and wainscoting, drab walls above, and sky-blue or blue and white ceiling. This practically duplicates the colors of nature, and produces a harmonious combination. Operating suits and protectors may be of the brownish white and ecru colors which their fabrics naturally assume. The floor should be waterproof, having a slant toward a drain opening. The room should not contain cases for storage of materials, but only such things

as are necessary for every operation—operating table, tables for instruments and dressings, and receptacles and stands for basins, and fluids.

Adjacent to the operating room should be the following accessory rooms: (1) The **instrument room** should contain cases for instruments. These cases should have glass fronts so that the contents are plainly visible. The doors should close tightly to exclude dust and moisture. An hygrometer may be contained in the cases to denote the degree of moisture in the air; and for the better preservation of the instruments some hygroscopic substance such as quicklime, to take the water out of the air, may be kept in the cases. The instrument room should be remote from the sterilizing room. Instruments of similar kinds and for specific operations should be kept together, always in the same place. (2) The **store room** should be provided with cupboards or cases with glass doors, and with drawers and shelves, in which are kept gauze, cotton, bandages, operating clothing, sheets, and other materials, sterilized and unsterilized, which may be required in the operating room. This room may also contain or have adjacent to it the wash basins for the nurses, and a nurses' toilet. (3) The **surgeons' room,** should be provided with lockers for the surgeons' clothes, wash basins, and a toilet. A shower bath is also a desideratum. The wash basins for both the nurses and surgeons should have hot and cold water emptying into large basins by spouts under which the hands may be held. The flow of water should be regulated by foot valves placed on the floor, and constructed in such a way that hot and cold water may be mixed as it flows from the spout. On a shelf above the splash board should be a glass vessel, containing sterilized hand brushes in solution; soft soap; nail scissors; towels; alcohol; and a clock or sand glass in order that the surgeon may have an idea of the time devoted to washing. (4) The **anesthetizing room** should be not immediately adjacent to the operating room, but separated by another room or corridor, in order that patients about to be narcotized shall not hear the sounds made by patients coming out of narcosis or have the consciousness of being next to the operating room. It should appear scrupulously neat, be quiet and well ventilated. The formidable instruments of narcosis should not be conspicuous. The essential furniture is a strong four-wheeled anesthetizing table (Fig. 53) upon which the patient may be brought from his bed, anesthetized, and conveyed to the operating room; and a small wheeled table for the anesthetist, upon which he should keep his emergency things, watch, chart, stethoscope, sphygmomanometer, gag, tongue forceps, etc. (5) A **recovery room,** containing one or more beds is also desirable, in which patients who may require some subsequent attention or special watching may be placed for a while before being sent to their beds. (6) The **sterilizing room** should be immediately adjacent to the operating room and to the store room. It should contain the sterilizing apparatuses, and may also be used to contain the flasks of sterilized solutions, water, etc., unless they are kept in the store room. (7) A **surgeon's private room** is also desirable, for the use of the surgeons. This may have a book case, skeleton, writing table, sofa, clothes closet, and bathroom. (8) A **laboratory** for surgical pathologic study, and a room for photographic and *x*-ray work, may be adjacent to the surgeon's private room.

The best organization provides that this operating room, with its accessory rooms, constitute a separate pavilion. Where such an arrangement can be carried out a second or (9) **special operation room** should be added. This is for special operations or for use in emergency when the main room is occupied. As an example of special use of such a room may be cited, operating upon an emergency septic case when a series of important clean



· · SURGICAL WING FOR A HOSPITAL · · J.P.W. ARCHITECT · · · NOTE— ANESTHETIZING ROOMS WITH COMMON N_2O_1 OXYGEN AND COMPRESSED AIR SUPPLY.

FIG. 101.—FLOOR PLAN OF OPERATING PAVILION IN CONNECTION WITH HOSPITAL.

operations must follow immediately after it. In the main operating room there should be provision for accommodating visiting physicians who desire to witness operations. This arrangement should depend upon the number of spectators to be expected, the important thing being that they shall be effectively debarred from entering the floor of the operating room. It is important that the windows and ventilation of the operating room be so constructed as to exclude dust as much as possible and flies absolutely. A floor plan of an operating pavilion is shown in Fig. 101.

For entirely separating the spectators from the operating room, a camera may be arranged directly over the operating table, the view from which after being focused on ground glass is reflected by a prism onto a screen where it may be seen by the observers.

An elaborate outfit, such as above described, is not absolutely necessary. Good surgery can be done in a simple room of pine boards with a plain wooden operating table. The prerequisite for success is ability to secure asepsis. The advantages of the modern arrangement of operating rooms is that it provides for the best cleanliness attainable, and makes possible a perpetual maintenance of this cleanliness even though operations are frequently done upon septic cases.

Operations in private houses often become necessary. A well-lighted room should be selected. Draperies, carpets, curtains, pictures and all unnecessary things should be removed. The walls and woodwork should be wiped down with a moist cloth, or, if not waterproof, the cut surface of a loaf of bread may be used to remove the dust. The floor should be scrubbed. In place of an operating table a kitchen table may be employed or boards laid upon wooden horses. The kitchen furnishes pots and basins for solutions. All of these things should be scrupulously cleansed. It should be borne in mind that bichloride of mercury solution quickly deteriorates when contained against metallic surfaces.

Operations in a tent, as practised in military surgery, are most satisfactory. The good ventilation present secures better hygiene for the surgeon and better resistance for the patient. I have never been able to secure better results or operate with greater satisfaction than I have in a tropical atmosphere, in an open tent, with a plain pine operating table. The drawback in such work in the open air is that pulmonary anesthetics operate slowly. Ether, because of its rapid evaporation, is practically impossible; and chloroform must be used in much larger amounts than indoors.

ARRANGEMENT OF OPERATING PERSONNEL, INSTRUMENTS AND MATERIALS

In the organized operating room the best results are secured by having a systematic placing of the tables, and appurtenances. The patient lying upon his back, usually the surgeon stands upon the right side of the table. The first assistant stands on the other side opposite him; the second assistant at the surgeon's left, and the third assistant at the left side of the first assistant. The *instrument nurse* stands back of the surgeon, between him and the instrument table. The **sponge nurse** stands between the assistants on the other side and the sponge table. In simple operations one nurse may pass instruments and sponges, having both on a single table (Fig. 102).

In addition to this personnel and the anesthetist there should be a **runabout nurse** or orderly whose hands are not kept sterilized and whose function is one of general usefulness. The **instrument table** should be covered with a sterilized cloth; if it has more than one shelf each should be covered.

Nothing unsterile should be placed upon it. The run-about nurse fetches unsterile things when they are desired. The instruments and suture materials should be spread out in orderly arrangement. The sponge nurse has upon her table, besides sponges, also towels and cover sheets.

In the direct passing of instruments and sponges they should be handed to the person who is to use them, and placed in his hand in the position in which they are required for use. When all is ready to begin, it is a good plan to have placed upon a small instrument table, so constructed that it swings across the patient close to the field of operation, the knife, forceps, hemostats and sponges, required for immediate use. This table should be covered with a sterile draw-cover. As the operation proceeds, the well-trained instrument and sponge nurses keep laid out within reach of the

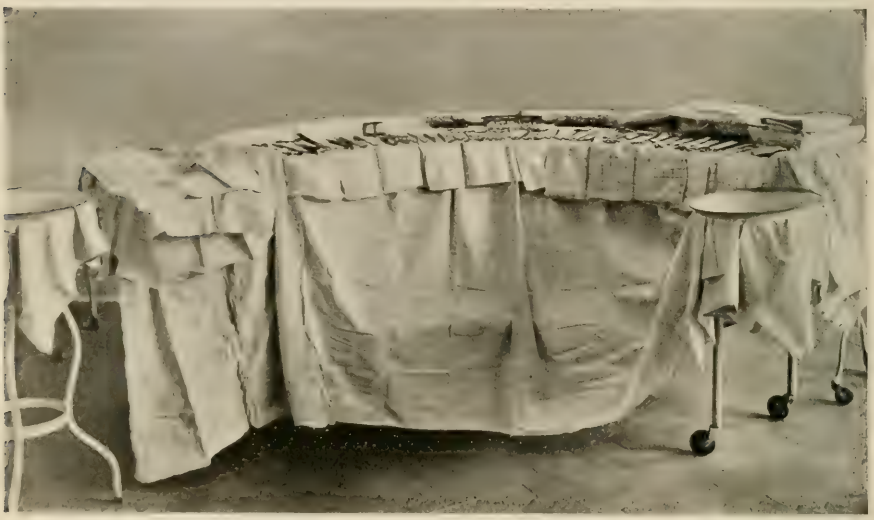


FIG. 102.—TABLE FOR INSTRUMENTS AND SPONGES READY FOR OPERATION.
All protectors, towels and instruments have been sterilized by heat.

operator just the things that he is about to use, and remove the things no longer required. Soiled sponges should not be left lying about but should be disposed of. The clean sponges should be placed together, and soiled sponges should be deposited separate from them. Instruments which are in frequent use should be rinsed in sterile water occasionally when the opportunity offers, to remove the blood, and then put back in reach of the surgeon. Basins of sterile water should be handy for rinsing the hands (Fig. 103).

The conduct of an operation should be quiet and orderly. No conversation not pertaining to the immediate work should be indulged in. Brief orders distinctly delivered need be about the only words spoken. The amenities of etiquette of the parlor do not prevail in the operating room. The less talk the better. The loquacious sputtering surgeon is obsolete. Nor will the interest of the patient permit clinical lecturing by the surgeon during an operation. What he has to say of the case should be said before and after the operation. While operating he should devote himself exclusively to the mechanical work at hand. His one function is to do what is best for the patient. This is all he has to think of. His interest during the

operation should be centered in helping the patient, and not in instructing the bystanders (Fig. 104).

In most cases the run-about nurse can act as assistant to the anesthetist. Anything, concerning the condition of the patient, which has a bearing upon the operation, which the anesthetist desires to communicate to the operator, should be addressed to the first assistant, who will transmit it to the operator or not as he thinks best. The operating surgeon should

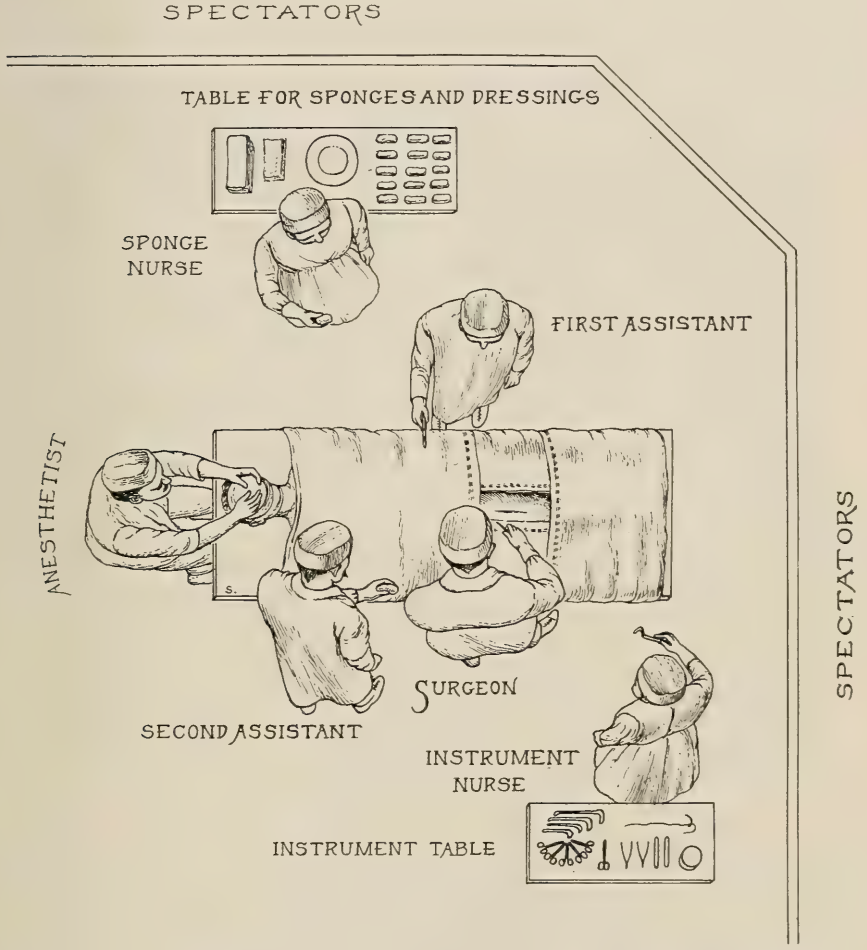


FIG. 103.—FLOOR PLAN OF OPERATING ROOM, SHOWING POSITIONS OF SURGEON, ASSISTANTS AND APPURTENANCES DURING OPERATION.

not feel that he must keep an eye on the anesthetic; but he should feel that one of his assistants, who is connected with the wound, is keeping in touch with the patient's general condition. In operations under local anesthesia or in operations in the chest and abdomen a screen (Fig. 45), made of a half hoop covered with a sterile cloth, may be interposed across the upper chest to shut off from the field of operation the patient's head or the unsterile operations of the anesthetist.

The **counting of sponges and instruments** is important because they are sometimes accidentally overlooked and left in the wound. Before an operation the nurse in charge should know just how many sponges and instruments of each kind have been laid out for a given operation. These things should be kept track of with accuracy. Flat-gauze sponges, such as are used in abdominal operations, should have a number stamped indelibly in one corner. Besides the number some other symbol, such as a letter, should be used to designate the size. Lockwood puts fifteen small sponges in a package each sponge marked A and numbered serially 1 to 15. This package is marked A15. The sponges next larger are similarly marked B10.

FIG. 104.—OPERATING-ROOM SCENE DURING OPERATION.

The package of five handkerchiefs or intestinal towels is marked C5. At the end of an operation whatever series is used should be fully accounted for. A wound should not be closed until the nurse has reported that all sponges and instruments have been counted and found correct. This care, besides preventing accident, also makes for a more orderly arrangement and care of the appurtenances of operation. Some surgeons use only sponges on holders, and flat sponges having long tapes which can not be lost sight of.

PERSON OF THE SURGEON AND ASSISTANTS

Persons engaging in surgical operations should be cleanly in person and possess healthy skin. The skin of the hands should be free from cracks and eczema. Long hair and beards are objectionable because of their dirt-carrying properties. Short hair and shortly cut beard or shaven face are the badge of the surgeon. The man who is most justified in giving scrupulous

care to his finger nails is the surgeon. He should wear gloves more than other men. He should refrain as much as possible from touching with bare skin infective things. The better care he takes of his hands and his health, and the more he wears rubber gloves when coming into contact with septic cases, the less necessary will be rubber gloves in clean cases.

Before operating, the street clothes should be replaced by an operating suit, consisting of a pair of white linen or drilling trousers and a short sleeved jacket. The best shoes for standing the wet of the operating room are the well-oiled, heavy shoes of brown leather such as are made for fishermen and procurable at shipping centres. The surgeon should get them three or four sizes larger than his usual wont and add a pair of insoles. He should cover his hair with an operating cap and his mouth and beard with a mask (Fig. 21). The latter prevents particles of saliva, projected when speaking, from entering the wound. Hair projecting underneath the cap may wisely be moistened. After cleansing his hands, a sterilized operating gown should be put on. Rubber gloves may or may not then be drawn on.

Cleansing of Hands and Forearms.—The hands should be scrubbed in warm water and soap with a sterilized brush that is not too harsh. The finger nails should not be "cleaned," as was once so much harped upon; they should be cut as short as possible, and when that is properly done there is no subungual space to be "cleaned." The nails are best cut after they have been soaked a little in the warm water and soap. The hands should be scrubbed for five minutes or longer, or until the intelligence of the surgeon assures him that he has removed all the removable material possible without doing damage to the skin. Soft soap is best.

A good soap is made of green soap 3, alcohol 1, glycerin 1, water 1, oil of bergamot $\frac{1}{8}$ part.

This scrubbing of the hands and forearms is a part of the operation for the saving of the life or ameliorating the sufferings of the patient, and it should receive the same conscientious and intelligent attention as is accorded to the rest of the operation. It can not be done well thoughtlessly. Each surgeon should regularly practise the cycle in which he washes. Beginning with the palm, the operation should proceed to the fingers, finger nails, interdigital spaces, backs of fingers, back of hand, back of wrist, front of wrist, anterior forearm, posterior forearm, etc. Each finger nail should receive attention. Around and around the scrubbing should go. Not the clock, but his own conscience tells the surgeon when he is done. Too many beginners are slipshod in this important operation, scrubbing away in one area for dear life to the neglect of others while they talk or think of some other thing. The washing is intended to remove the dirt and loose epithelium. The skin follicles, containing oily and sebaceous secretions and a few bacteria (notably the staphylococcus pyogenes aureus and albus), can not be cleansed nor sterilized. In order to further wash out fat and insoluble matter the hands should be washed in alcohol, preferably a 1:2000 bichloride of mercury solution, and then the hands and forearms immersed for five minutes in a 1:2000 watery solution of bichloride of mercury. After this, should the hands accidentally come into contact with any unsterilized object, they should be washed again and immersed in bichloride.

If the hands present any little scratch or abrasion it should be dried with alcohol, touched with tincture of iodin, and painted over with collodion-ether. The presence of a pimple or pustule should exclude the hand from operation unless it is covered with rubber.

After soaking in the bichloride solution the hands are ready for most operations. But it should be borne in mind that absolute asepsis has not

yet been secured. Much pressure upon the skin, scraping or rough handling will cause some bacteria to be detached from the deep follicles. The ordinary wound takes care of these and they are destroyed the same as are the bacteria from the air which enter wounds. Many expedients for cleansing the skin and overcoming this weakness in the aseptic chain have been employed.

The *permanganate of potash* method consists in immersing the hands in a hot saturated solution of this salt after they have been scrubbed in soap and water, washed in alcohol, and soaked in bichloride. The permanganate is allowed to dry on the hands forming a coating which also covers the mouths of the follicles. After the operation it is removed by washing in a saturated solution of oxalic acid.

The *tincture of iodin* may be used to disinfect the surgeon's hands. As iodin is irritating its use has been difficult. The bisulphite of soda removes it. If the hands after being immersed in tincture of iodin, are washed with a solution of bisulphite of soda, the iodin is dissolved away. The bisulphite is an antiseptic and the skin after this treatment is left sterile. Perspiration is inhibited for an hour or more. It may be removed from the skin also by boiled or raw starch, ammonia water, hydrogen peroxide, ether, liquor potassii arsenitis, hyposulphite of soda, or alcohol. Some surgeons are able to use iodin constantly without irritation or coloration by decolorizing with ammonia immediately after the hands have been dipped in the iodin.

The *cresol-acetone* method of Konrad (Wein. Med. Woch., No. 21, 1911) is useful for hand disinfection. A 2 per cent. solution of chlormetacresol is made in a mixture consisting of 2 parts of 96 per cent. alcohol and 1 part of acetone. The hands are first washed with warm water and soap for half a minute without using a brush, and the nails cleaned. The hands are then washed for three or four minutes in the above solution, using a soft brush or a flannel cloth. The skin has been found sterile after this. The solution may be filtered and used again.

The *tannin* method of skin sterilization consists in washing the hands for two minutes with gauze, wet with a 5 per cent. alcoholic solution of tannin. Bacteriological tests show that the skin is sterile after this treatment.

The *acetone-pyxol* method consists in washing the hands in acetone (40 parts), pyxol (2 parts), and alcohol (60 parts) (see page 70). This gives better sterilization with less irritation, perhaps, than can be secured by any other method.

Rubber gloves are the best guarantee against carrying infection with the hands. They are kept dry after sterilization. The hands should be cleansed with the same care as though gloves were not to be worn, because the prick of a needle or a slight tear at some unexpected time during the operation may expose the skin. For putting on gloves, after washing and disinfecting the hands, the hands should be dried with a sterile towel and dusted with sterilized starch or talcum powder. The nurse, with sterilized gloved hands, should take hold of the glove, turn back the cuff over her own fingers so that the skin of the surgeon can not touch her glove, and hold the glove open for him while he inserts his hand. The same process is repeated, the surgeon not adjusting the fingers until he can do so with the covered fingers of the other hand (Fig. 105). In putting on gloves without assistance they may be handled with a piece of gauze or a towel. For dusting the hands nothing is more convenient than little squares of gauze, containing the powder, the four corners being taken together and tied. This makes a little bag which can be sterilized, and through the meshes of which the powder sieves out on the hands.

The use of gloves is demanded because of the difficulty of rendering the skin sterile, and the principle should be carried out to the degree that the outside of the glove shall not be touched by the skin, otherwise the value of the gloves is not proved.

When put on wet, the gloves may partly be filled with bichloride solution or sterile water, or they may be drawn on with the hand submerged in solution. This is done only in emergency when there has not been time to dry the gloves, as the moisture macerates the skin, brings up the bacteria from the skin follicles, and increases the danger of infection from needle pricks or tears.

FIG. 105.—NURSE DRAWING ON SURGEON'S GLOVES.

Wet gloves and sweaty hands macerate the skin and bring out the bacteria from the skin follicles. The greater ease with which wet gloves are manipulated prompts surgeons to use this method more than the dry method.

While rubber gloves insure against infection from the hands they interfere somewhat with the tactile sense and with the facility with which things can be grasped. In certain operations their use is imperative. These are such operations as suturing the fractured patella or olecranon, operations involving joints which are to be closed without drainage, operations for hernia especially ventral and umbilical hernia, nerve suturing, tendon suturing, and, in short, all operations in which the slightest infection militates against the success of the operation. In operations upon the vermiform appendix, uterus and adnexa, intestines, or, in fact, most abdominal operations, better results will generally be secured without gloves, for the reason that unblunted tactile sense is necessary and the peritoneum quickly destroys a few white skin cocci. It is a wise rule to require assistants and nurses to wear gloves; but the surgeon must formulate his own policy. The use of rubber gloves by the surgeon has steadily increased in favor until now most surgeons use them in all clean operations.

Other methods of hand cleansing and protection come and go. Solutions of rubber and other materials have not found general acceptance. An aid in keeping the hands in good condition, if the skin tends to be dry, is to rub them with some lanolin after washing; or the following mixture—compound tincture of benzoin 1 part and glycerin 4 parts.

PREPARATION OF PATIENT FOR OPERATION

General Preparation

For operation the patient should be in the best general condition possible with reference to physical resistance and mental hopefulness. A patient who is plunged in melancholy should not be operated upon, except in emergency, if there is a possibility of inducing a better morale. Before operation the general condition should be well investigated. The heart, circulation, lungs and kidneys should be examined lest some disease exist which should be remedied or which might modify the steps of the operation. The patient should have a bath. The day before operation a laxative should be given; after which, if a general anesthetic is to be used, solid food should not be allowed. On the morning of the operation it is well to give an enema. If the patient is to take ether or chloroform no food should be allowed for six hours before operation.

The prevention of acidosis is important in major operations and in all operations upon people with damaged glandular organs or serious constitutional disease. G. W. Crile (Annals of Surg., Sept., 1915) showed the importance of this subject. Operative trauma and inhalation anesthesia always cause the formation of acid by-products which have a deleterious effect upon the brain and the important glandular organs, notably the adrenals and the liver. To minimize this all of the measures for the prevention of shock should be employed. The patient should have had a good night's rest and be free from anxiety. The following preliminary treatment experience has shown reduces the danger of acidosis:

Sodium bicarbonate 2 Gm. (30 grains) in 100 c.c. (3 ounces) of water thrice daily half an hour before meals for two days preceding the operation.

Sodium bicarbonate and glucose 15 Gm. (4 drams) of each in 250 c.c. (8 ounces) of water as an enema to be absorbed, twice daily for two days before operation.

During the two days preceding operation large quantities of water should be taken.

For twenty-four hours preceding operation care should be taken that no foods which cause the formation of much gas, such as egg albumin, should be taken.

Castor oil, 15 c.c. (½ ounce) should be taken in the morning of the day preceding operation. A soap suds enema should be given on the night before and on the morning of operation.

Strontium bromide, 2 Gm. (30 grains), should be given the night before operation, to insure a good night of sleep.

Morphin, 0.008 Gm. (⅛ grain), and scopolamin, 0.0006 Gm. (1/100 grain), should be given one hour before the anesthetic is begun.

Nitrous oxide and ether anesthesia are recommended.

During the operation all of the measures for preventing shock should be used. Especially is quinin and urea infiltration of the wound region valuable (see Shock, page 213).

After the operation adrenalin chloride (1 : 1000 solution), 1 c.c. (15 minims), should be given every 6 hours for three doses. Pituitrin, 0.3 to 0.5 c.c.

(5 to 8 minims), given six hours after operation and repeated in one hour acts as a diuretic, and sustains blood-pressure. If there is pain, it should be relieved by codein, 0.06 Gm. (1 grain). Morphin should rarely be necessary. Strontium bromide gives sleep. The sodium bicarbonate by mouth should be continued as before operation. The above is the course of treatment recommended by G. W. Quillian (Annals of Surg., April, 1916).

G. W. Crile increased the reserve alkalinity by giving about 2000 c.c. of normal saline solution by hypodermoclysis the day before the operation and the morning of operation, and during the same period a total of 7 Gm. (100 grains) of bicarbonate of soda by mouth or rectum.

Acidosis therapy by alkalinized transfusion was worked out by A. O. Gettler and E. Lindeman (Jour. Am. Med. Assoc., Feb. 24, 1917). In the cases of seriously sick persons bicarbonate of soda can not be given in adequate amounts by mouth or rectum. Hypodermoclysis is painful and intravenous infusion may be dangerous. To meet the indications in patients suffering with acidosis, the alkali may be introduced through the medium of the blood of a healthy person. Ten or 20 Gm. (150 or 300 grains) of sodium bicarbonate are given to the donor every two hours for eight doses. Usually the larger dose is used. The greatest alkalinity of the blood is reached about thirty minutes after taking the last dose. At that time, 500 to 1500 c.c. of blood should be removed from the donor's vein, mixed with one-third of that amount of Locke's solution and injected into a vein of the patient. If the patient is in an extreme state of acidosis fully 1000 c.c. of blood should be used, but before making the injection one-third or one-half of that amount of blood should be removed from the patient.

In the average case of pronounced acidosis, 400 c.c. of blood may be removed from the patient; 1000 or 1200 c.c. should be taken from the donor, mixed with 300 c.c. of Locke's solution, and injected immediately into the patient. After the transfusion the patient should be given soda solution by rectum. After several days, if necessary, the operation may be repeated with a smaller amount of blood. The blood of the donor should have been tested for compatibility with that of the patient before it is taken.

As a preliminary to operation in serious cases the usual chemical and microscopic studies of the urine and blood are not enough to furnish information as to the patient's ability to withstand operation. For abdominal and urinary operations the phenolsulphonephthalein test of kidney function should be made. Blood studies are also important. Tests of the H-ion content of the blood and a study of the alveolar air are valuable in determining the anesthetic to be used.

Local Preparation

The **iodin preparation** is carried out as follows:

On the day preceding the operation the skin of the area to be operated upon, and widely about the same region, should be scrubbed with warm water and soap, and shaved. The scrubbing should be done with a soft brush or with gauze so as not to scratch the skin. The patient goes to the operating room. On the operating table, the operative area is exposed. If the skin shows any signs of having been moistened with perspiration or other watery fluid, it should be washed with alcohol. Tincture of iodin of 5 per cent. strength is then painted over not only the operative area but any surrounding skin that may be exposed during the operation. Two coats are applied.

In the case of children and light-skinned persons 3 per cent. strength may be used. Water on the skin renders the iodin ineffective. It is for

this reason that washing with water should not be practised just before operation, if iodin is to be used. When cleansing is necessary in emergency cases it may be done with alcohol or benzin. Some surgeons prefer to use the full strength tincture of iodin in all cases, and, if the skin is sensitive, wash it off with hyposulphite of soda or alcohol after it has acted for a few minutes. A 5 per cent. solution of hyposulphite of soda swabbed over the skin five or ten minutes after the iodin has been used effectively removes it, and allows the iodin to accomplish sterilization but not irritation.

Iodin should not be used in cases of hyperthyroidism as there is already an excess of iodin in the blood, and serious constitutional disturbances may be precipitated.

An advantage of iodin is that in emergencies, without any preliminary scrubbing or cleansing, the tincture of iodin may be painted on the skin and the operation proceeded with. Sterilization in these cases seems to be satisfactory. A disadvantage is that it produces adhesions if it touches the peritoneum.

E. McDonald (Surg., Gyn. and Obs., xxi, 1915) advocated the following **Acetone-pyxol** solution:

Acetone (commercial)	40 parts
Denatured alcohol	60 parts
Pyxol	2 parts

This solution seems to be more strongly germicidal than tincture of iodin without being irritating. It is being widely employed both for sterilizing the skin before operation and for sterilizing the surgeon's hands. Water up to 10 per cent. or more does not interfere with its action; it can, therefore, be used if the skin is wet or after the surgeon has washed his hands with soap and water.

The **picric acid method,** in which 1 per cent. alcoholic solution is used the same as iodin, is as effective as iodin, and less irritating. When this method is used the skin should have been washed with soap and water the day before operation.

These chemical germicides are applied with a ball of gauze, about 3 or 4 cm. (1 or 1½ inches) in diameter, held in a sterile pair of forceps. The place of the line of incision should receive especial attention. All parts of the skin which will be touched by hands, instruments, or gauze, which are to come directly or indirectly in contact with the wound should be sterilized. In the interest of safety, the skin sterilization should extend well beyond the operative area which is not to be covered by protectors. That is, the skin disinfection should extend well under the cloth coverings of the wound environment.

If for any reason iodin, picric acid, or acetone-pyxol-alcohol, or any of the more penetrating antiseptics is not available or is not to be used, mechanical cleansing with soap and water must be resorted to. If this mechanical cleansing can be combined with one of the old antiseptics, such as corrosive sublimate or phenol, it may be made more effective.

The **aseptic and antiseptic mechanical cleansing method** may be used as a preliminary to iodin sterilization, although the iodin is probably effective without it. The method of sterilization without iodin is as follows:—

On the day preceding the operation the skin of the area to be operated upon, and widely about the same region, should be shaved and scrubbed with warm water and soap with the same care that the surgeon's hands are scrubbed. Scrubbing should be done with a soft brush or gauze so as not to scratch the skin. Following this it should be wiped off with bichloride

alcohol (1:3000), and be covered with gauze wet with 1:3000 bichloride watery solution, over which towels are laid and held on with a binder or bandage. In the case of tender skins of women and children, the bichloride should be omitted from the alcohol and boro-salicylic or boracic acid solution substituted for bichloride in the final skin dressing. The object of leaving on this wet pack is for its antiseptic property and also to secure a softening and maceration of the epithelium and of the contents of the skin follicles to permit their more ready removal at the subsequent washing. Immediately before the operation, after the patient has been placed upon

FIG. 106.—OPERATING FIELD READY FOR OPERATION.
Skin sterilized with iodin which causes dark color. Environment covered with sterile protectors.

the operating table and the anesthesia is being established, the gauze and towels should be removed the field of operation surrounded by sterile towels and the final cleansing done. The skin should again be scrubbed with soap and warm water, a soft brush or a piece of gauze being used. The soap should be washed off with sterile water or bichloride solution. This should be followed by a cleansing with bichloride-alcohol, 1:3000. The patient should not be sprinkled and douched with water in such a way that he lies in a puddle and is surrounded by wet fabrics during the operation. The water used in cleansing should run off, and the patient's skin should be left dry and protected by dry things.

In preparing the abdomen, especial care should be given to cleansing the umbilicus. This preliminary cleansing of the skin should be done by an intelligent and conscientious assistant who understands the principles

of asepsis and antisepsis, or it should be done by the surgeon. The cleansing or aseptization having been done, all the environment of the field of operation is to be covered with sterile sheets or towels (Fig. 106). For this purpose the sheet with an oblong hole in it is best.

Emergency preparation must often be done when immediate operation is required. In this event the only cleansing is done at once. The site of operation is shaved, washed with alcohol and treated with iodin or one of the solutions above described. The skin, provided it is dry, and not covered with gross dirt, can be rendered aseptic without any scrubbing at all, if necessary, by painting it thoroughly with one of these alcoholic solutions.

Special Preparations.—In operations upon the *scalp* the hair should be shaved widely about the operative field, and in operations upon the *meninges* or *brain* the whole scalp should be shaved. Operations upon the *eye* should be preceded by irrigation of the conjunctiva with boracic acid solution. The *nose* is susceptible to cleansing with saline solution. Operations within the *mouth* should be preceded by mouth washing with boric acid solution, especial attention being given to the cleansing of the teeth. In fact, preceding all operations under pulmonary anesthesia, it is wise to give attention to the cleansing of the mouth in order to reduce the danger of postoperative *pneumonia*. Decayed teeth should be filled or drawn, and for several days before operation the mouth should be washed at frequent intervals. Decayed teeth, present at the time of operation, should be dried and treated with tincture of iodin or phenol. These precautions will help to reduce the mortality from pneumonia following operations especially upon the mouth, larynx, trachea, thorax, and upper abdomen. Before operating upon the *stomach* or *intestines* it is best that no solid food should have been taken for twenty-four hours, the bowels should have been thoroughly moved, the lower bowel cleansed with an enema, and the stomach washed out. Up to within six hours of the operation whey, albumin water, broth or glucose may be allowed. Operations upon the *genitals* and *anus* require shaving of the genital region. Preceding *perineal* and vaginal work, the *vagina* should be washed out with a sponge or forceps, warm water and soap, followed by aseptic irrigation. *Intra-uterine* operations should follow a swabbing out of the cervical canal with tincture of iodin. Operations upon the *penis* are wisely preceded by the treatment of any suppurative condition present. A few days in bed are essential preliminaries for operations upon the congested *prostate, bladder* or *kidney*.

There are certain *conditions requiring special preparation and operative consideration*. *Shock*, if it is profound, contraindicates against most operations. Measures should be taken to help the patient overcome the shock, but operation which would add still more shock should rarely be done (see Shock, page 213). The same may be said of extreme *prostration*. Only experience can teach the surgeon to recognize the degree of prostration which precludes operation. *Obesity* is important in that the obese bear well abstinence from food; under anesthesia they easily become cyanotic from limitations of respiratory movements and from excess of mucus and saliva secreted; and their proneness to fatty heart should be borne in mind.

High-arterial tension should be discovered before operation, and measures for its correction instituted. With these patients it is imperative that the anesthesia be made as short as possible. *Alcoholism* induces a condition not unlike the above. A large amount of ether is required to induce narcosis, the stage of excitement is long and violent, and cyanosis easily supervenes. Before operation, the alcoholic should have been upon a simple, nourishing,

well balanced diet; if much gastritis is present the stomach should have been washed out for a few days; and the bowel should be well emptied. The narcosis should be as short as possible, and every precaution to prevent pneumonia must be taken.

In *jaundice*, due to malignant disease of the bile passages, and other conditions in which the coagulation time of the blood is dangerously retarded, the loss of blood and the possibility of post-operative hemorrhage may be reduced by increasing the *coagulability of the blood* by the administration of calcium chloride in amounts of 4 to 6 Gm. (60 to 90 grains) daily for three or four days or dried thyroid extract to the amount of 0.55 Gm. (9 grains) daily for from three to seven days before operation. Pituitary extract, given hypodermatically in doses of 1 c.c. (15 minims) about fifteen minutes before operation, causes a shortening of the coagulation time of the blood. Just how much practical value these substances possess is still an unsettled question. Some of the other conditions in which coagulation is slow are anemia, hemoglobinemia, purpura, anasarca, asphyxia, alcohol and other poisonings, and hemophilia. *Hemophilia* demands not only constitutional treatment before any operative procedure is instituted but during the operation every bleeding point must be controlled by ligature, suture, cauterization or pressure.

The *status lymphaticus* is a symptom complex, the nature of which is not understood; it exists in weakly children, which when operated upon display a marked proneness to infection, so that more than the ordinary precautions against infection are necessary. They bear general anesthesia poorly, and sudden death is apt to occur either during the narcosis or shortly after.

The presence of *diabetes* renders operative wounds more susceptible to infection, and, therefore, demands extraordinary precautions. Everything to prevent shock should be done in these cases. The shock caused by anesthetic and operation may precipitate an attack of coma. Constricting bandages and mass ligatures should be avoided. The patient should be gotten in the best possible general condition. Hyperglycemia favors infection, and acidosis is constitutionally dangerous. Only imperative operations should be done on diabetics. The glycemia may be reduced. A mixed diet of carbohydrates may be used in non-emaciated diabetics. Patients with acidosis should have a diet of dried vegetables, oatmeal, and milk. Alkalies are of value. Before the operation 40 Gm. (1⅓ ounces) of sodium bicarbonate should be given; and large doses should be administered by mouth, subcutaneously, or intravenously after operation. Vegetables and oatmeal and milk broth should be the first foods used. The alkali may be given in 5 or 10-Gm. (75 to 150-grains) doses half an hour before every two or three hourly feedings of oatmeal, and one or two doses at night.

Chloroform is a most objectionable anesthetic in diabetes. Infiltration anesthesia is undesirable. Ethyl chloride seems to be safe. Ether is best. Post-operative coma must be warned against. Acetone, diacetic acid, and beta-oxybutyric acid in the urine indicate serious trouble. The operation should be completed as quickly as possible. When wounds do not heal well the urine should be examined for sugar.

In *kidney disease* operations are serious chiefly because of the danger of damaging the kidneys by irritating materials which must be excreted from the blood. The blood changes and defects of metabolism incidental to general narcosis and surgical operations may so irritate the kidneys as to interfere with their vital excretory power. In operations performed in

the presence of acute or chronic nephritis the points to be borne in mind are, that the patients vitality should be conserved, as little anesthetic as possible should be used, blood should be saved, the operation should be done quickly, the surface of the body should be kept warm, proteid feeding should have been minimized, and toxic materials in the blood should be freely diluted and washed out. An index to the execretory power of the kidneys is found in the freezing point of the blood. When this is above −0.60°C. the outlook for operation is favorable; when it is −0.58°C. operation may be done without fear of kidney failure (see Tests of Kidney Functioning, Vol. III).

In *prostatic cases* the same care should be applied as is used in cases of kidney disease. The special preliminary treatment which is of the greatest importance is preliminary drainage of the bladder.

The preparation of *anemic patients* for operation requires especial consideration. The character of the anemia should be determined. If loss of blood is going on or blood is being destroyed this condition should be remedied (1) by rest; (2) by direct hemostasis such as ligation, packing, local coagulants, cautery; and (3) by indirect hemostasis such as transfusion, drugs, and radiotherapy. After hemorrhage or blood destruction have been checked reconstructive treatment is called for by rest, fresh air, food, treatment of specific disease, and transfusion.

Operations required in the presence of *anemia* are best not done with general anesthesia if the anemia is pronounced. Every drop of blood must be spared, and blood-pressure must be maintained. It may be the loss of a teaspoonful of blood that turns the scales against the patient.

In *nervous diseases* the possibilities of postoperative insanity, or delusions and incriminations must be considered. *Pulmonary disease* often contraindicates general anesthesia because of the danger of exciting pneumonia. When the heart is good, chloroform is preferred to ether as being less irritating to the respiratory mucosa. *Cardiac disease* requires especial watchfulness lest the circulation be unbalanced. Local anesthesia is usually preferable. Patients suffering with *tuberculosis* must be spared general depression and pulmonary irritation. That means that the nourishment must be kept up, operations must be short, and they must immediately after operation be put out of doors. *Syphilis* demands especial consideration because the wounds of the syphilitic do not heal well. Constitutional treatment should not be discontinued. The surgeon and assistants should guard themselves from infection. Every one participating in the operation, including the anesthetist, should be advised that the patient is syphilitic.

In *acute septic infections* the surgeon and assistants must protect themselves as well as the patient from infection. *Pregnancy* does not contraindicate operation. Surgical conditions arising during pregnancy, in which operation, if postponed, would endanger the life or health of the patient, should not be deferred on account of the pregnancy. Pregnant women are very tolerant of operation, and if carefully treated are not prone to abort. Statistics seem to show the women are most apt to lose their babies at the times which correspond to the menstrual periods and at the third, fourth, and eighth months. These times should be avoided if possible.

In *thyrotoxicosis*, such as is seen in exophthalmic goitre, operation should not be done during an acute attack. Rest is absolutely necessary as a preliminary to operation. There is no such thing as emergency operation in these cases; when there is an emergency, operation is contraindicated. Every mental irritation should be avoided.

Care of the Patient During Operation.—During operation the wound should be protected from contamination by continuing the strict aseptic

precautions inaugurated in the preparation for operation. It should be the business of an assistant to see that the towels and protectors are properly arranged, and if soiled replaced by clean ones. Any one observing a breach of asepsis should quietly communicate the fact where the information will be of immediate service to the patient. Visitors with dusty hair and clothes should not be allowed too near the wound, instruments or sponges.

The protection of the patient against shock should concern the operator himself. The saving of blood, the avoiding of irritating sensory nerves, and the conserving of the natural heat of the body are the important things.

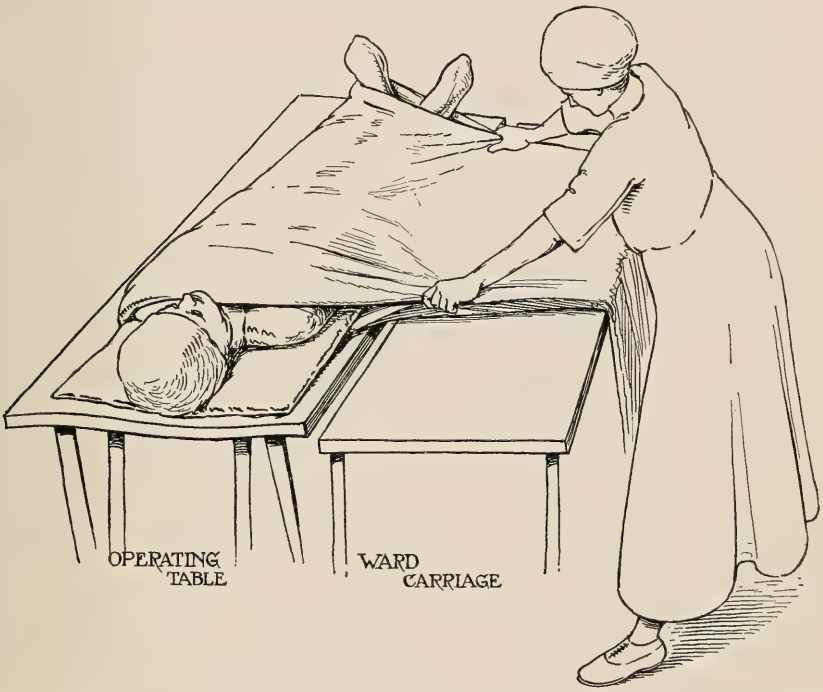


FIG. 107.—TRANSFER SHEET, SLIDING PATIENT FROM CARRIAGE TO OPERATING TABLE. The sheet may be left on the table and used to slide patient back to carriage. It extends from the shoulders to the feet.

Make the operation and the anesthesia as short as possible; expose and traumatize as little tissue as possible; and keep the patient warm. For the latter purpose half or quarter blankets which may be wrapped about the parts of the body not exposed in the operative field are useful. The patient should not lie in wet cloths, but the skin should be kept dry. A table having a bed of tubular metal through which warm water circulates is one of the practical shock-preventing expedients. A table arranged with a chamber under it containing twenty or thirty incandescent lights also gives satisfactory warmth.

It should be remembered that unconscious patients are not sensitive to strained positions and pressure, and that, if the patient is put in a position which would cause painful strain or pressure to a conscious person, he will suffer the pain after recovering from the anesthetic. It should be seen to that limbs are not in a strained position, or subjected to undue pressure. An arm

hanging over the edge of the table may be found to be paralyzed, from nerve pressure after the operation. The suspension of the legs by hanging the foot in a strap for perineal operations is unjustifiable as it puts a strain upon the ligaments of the ankle and hip which is bound to cause pain, if nothing worse, after the operation. All of the parts of the body should rest naturally and easily. A pillow should be placed under the lumbar spine when patients are lain prone on a straight table. If this is not done the strain on the ligaments of the spine and sacroiliac joints often causes bad backache. When the knees are flexed over the bent table in the lowered head position, a pillow should be placed at the angle of the table behind the knees. Post-operative discomforts and permanent damage to joints may be avoided by attention to these lessons.

For **moving unconscious patients** the wheeled stretcher is used. For transferring patients from the stretcher to the operating table and from the latter to the former, the two should be of the same height. A strong double sheet should be placed under the patient and under the pad and pillow upon which the patient is to lie when on the table. This sheet should then be carried around the body and envelop it as a loop. It should extend from the neck to the feet. When the patient is to be moved, the stretcher is wheeled to the side of the table, the two ends of this *transfer sheet* brought together, and by drawing upon them horizontally the patient is slid across from one surface to the other (Fig. 107). The sheet is left on the operating table, and used to transfer the patient back to the stretcher after the operation.

OPERATIONS

The best **time for operating** is in the early part of the morning when the vitality of both patient and surgeon are at their best. The *time consumed* in operating must depend upon the conditions to be met, but whatever they are, the wise surgeon makes his operation as short as possible. Every operation is productive of shock to a greater or lesser degree. The surgeon should never forget that he is doing something more than a mechanical job, and that the material with which he is working is suffering constant damage while he is at work.

Wounds are closed or left open, depending upon whether they are free from insurmountable infection or whether drainage is desired. The wish of the surgeon should be to restore as nearly as possible the structures to their natural positions.

The **dangers of operations** *per se* should not be lost sight of. The curative power of operations *per se* is not the only thing. The family of the patient should know that there is a hazard in every operation. Operation becomes necessary when the hazard, discomfort or objections to the disease are greater than the hazard, discomfort or objections of the operation. If the patient desires to discuss the hazards of operation he should not be deceived. His mind will be put at rest, however, when he is given to understand that the danger of operation is not so great as the danger of allowing his disease to go on, and that so far as hazard is concerned we may be constantly surrounded by greater dangers every day of our lives whether we ride or walk.

The Making of Wounds

Technic.—There are different ways of holding the scalpel. The best way is that which comes most natural to the operator. For making the ordinary skin incision the scalpel is best held lightly between the thumb and first finger as a violinist holds his bow (Fig. 108, *A*). For ordinary tissue dis-

secting, the knife is held as a penholder in writing (Fig. 108, *B*). For cutting resistant tissues the scalpel is held as a table knife (Fig. 108, *C*).

The stroke of the knife should always be deliberate and so regulated that the surgeon knows how deeply each stroke is to cut. As a rule, incisions should be made in the same general direction as the muscle fibres, nerves and vessels. Away from important structures a larger division of tissue may be made at each stroke of the knife.

In the region of large vessels or nerves the dissection should be made more carefully. The chief function of assistants is to place clamps on blood-

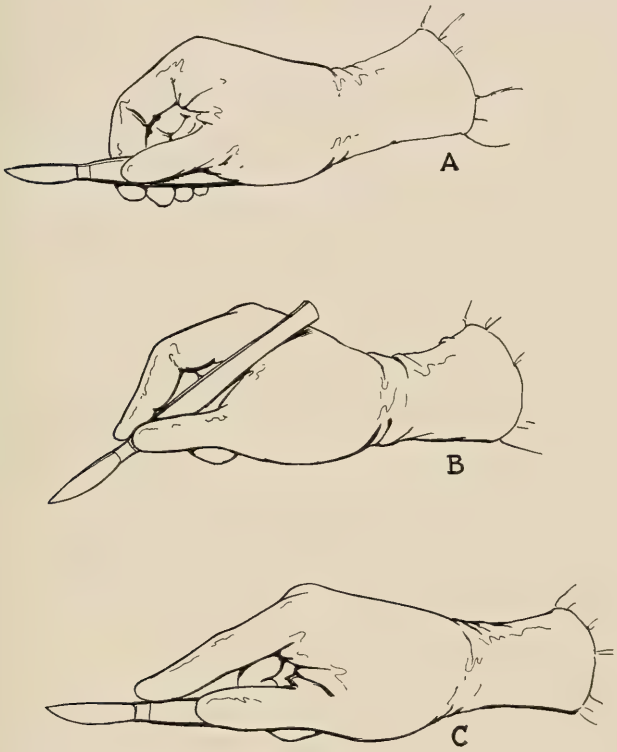


FIG. 108.—METHODS OF HOLDING OPERATING SCALPEL.
A, Violin hold; *B*, pen-holder hold; *C*, table knife hold.

vessels as soon as they are cut, keep the wound sponged dry, and the parts retracted so that the surgeon has a good view of the bottom of the wound. The cutting should not progress faster than the control of the bleeding. A couple of competent assistants, with the noses of their hemostats closely following the blade of the surgeon's knife, will clamp vessels so fast that the loss of blood is but slight, and but little sponging or pause in the operation is required. As the wound becomes filled with clamps one assistant may follow up and take them off. If the vessel is small the simple pressure of the clamp will be found to have stopped it. Other vessels will be controlled by twisting the clamp, the torsion closing the vessel. Others will require ligation. In clamping bleeding points, only the vessel itself should be seized. The skill of assistants is displayed in the ability to catch vessels without devitalizing a large amount of surrounding tissue.

The Treatment of Accidental and Infected Wounds

The first steps in the treatment of accidental wounds are to protect the wound from further infection and to arrest hemorrhage. Usually this is best accomplished by means of pressure until the cleansing of the skin has been completed (see Hemorrhage, page 334). The bleeding having been stopped the general condition of the patient should receive attention. Anemia (page 343) and shock (page 213) if severe should be treated according to methods described elsewhere. The cleansing of the wound is the next step and should be proceeded with immediately. A mistake often made is to treat accidental wounds in a fatalistic manner as though whatever damage has been done has been done and that is the end of it. They are often treated in bed or in some other bad environment. Such wounds should be taken to the operating room, dressing room or some place where cleansing can be thoroughly carried out. The patient should lie down. The surgeon should scrub his hands and prepare himself as for an operation. The wound area should be exposed and the environment protected. Disinfection with iodin should proceed as described above. In the absence of effective disinfectants a sterile sponge should be placed over the wound, and then the surrounding skin should be widely scrubbed with soap and water, shaved and washed. Some soap suds will not do a soiled wound any harm. The skin up to the wound should all be cleaned. The wound should then be washed out with warm sterilized salt solution or water to remove clots and foreign matter. In the case of large wounds all of this should be done under anesthesia. Devitalized and loose pieces of tissue should be cut away. If the wound has been made optically clean, it may be sutured, with or without drainage, depending upon its size, location, and probability of infection. A wound that has been much soiled may be left partly or wholly open and tamponed with antiseptic gauze.

Badly **soiled wounds** in which there is a high probability of serious infection are best disinfected with *tincture of iodin* or equivalent antiseptics, as described above. The iodin enters the tissues for a considerable distance where it remains for several days. It destroys bacteria and stimulates local protective action. With this drug it is possible to disinfect a dirty wound even though the foreign material is not removed. Such a wound with the dirt left in, if treated with iodin, is less dangerous than though all gross evidences of dirt are removed and iodin is not used. For a small wound iodin may be used in 10 per cent. strength. For a larger wound the tincture of iodin should be diluted with twice the amount of water. For emergency use ampules containing 3⅓ per cent. solution of iodin are put up ready for use. It is also put up in sealed glass tubes each containing 1 Gm. (15 grains) of iodin and 1½ Gm. (22 grains) of potassium iodide. The contents of a tube dissolved in 50 c.c. (13 drams) of water or alcohol give a solution of the desired strength for wound disinfection. After drying the wound and pouring in the iodin, it may simply be covered with a sterile protective dressing or plugged with gauze.

Liquefied phenol, instead of iodin, may be used in smaller wounds. It should be followed by alcohol. Suppurating wounds which are not freely open should be provided with large-sized drainage tubes to provide for the easy escape of pus.

Soiled wounds may be cleansed if seen within twelve hours; by the end of twenty-four hours it is rarely possible to remove or destroy the bacteria; and after the lapse of forty-eight hours it is practically impossible to secure disinfection excepting by prolonged treatment. Aseptic dressings may

be used in wounds which are sterile; but septic wounds are best dressed with antiseptic dressings.

For a full discussion of the treatment of infected wounds, see Inflammations, page 228, and Infected Wounds, page 237.

The **hot-air treatment** of suppurating wounds is similar to *heliotherapy*. It is applicable to superficial wounds, and especially to ulcers. Air, heated by an alcohol lamp, is driven into the wound by means of a pump worked by hand, foot, or electric power. Drying and death of bacteria are the results. Wounds treated in this manner seem to cicatrize more rapidly than when covered with dressings.

The **treatment of small wounds,** which are usually regarded as of little consequence and which require no suturing, should be by the same rules as are given for larger wounds. Every wound is important. It should be sterilized with tincture of iodin, or thymol, or other antiseptic and protected by a dressing of gauze or other occlusive substance.

Any wound which may become infected or which has become infected should be treated by *rest* as much as possible. Even without antiseptic treatment, if the part can be kept quiet, infection is not apt to spread. It is just as important to carry a wounded hand splinted in a sling as to keep an infected peritoneum quiet. If a wounded part is immobilized like a fracture, infection need not be feared.

The Closure of Wounds

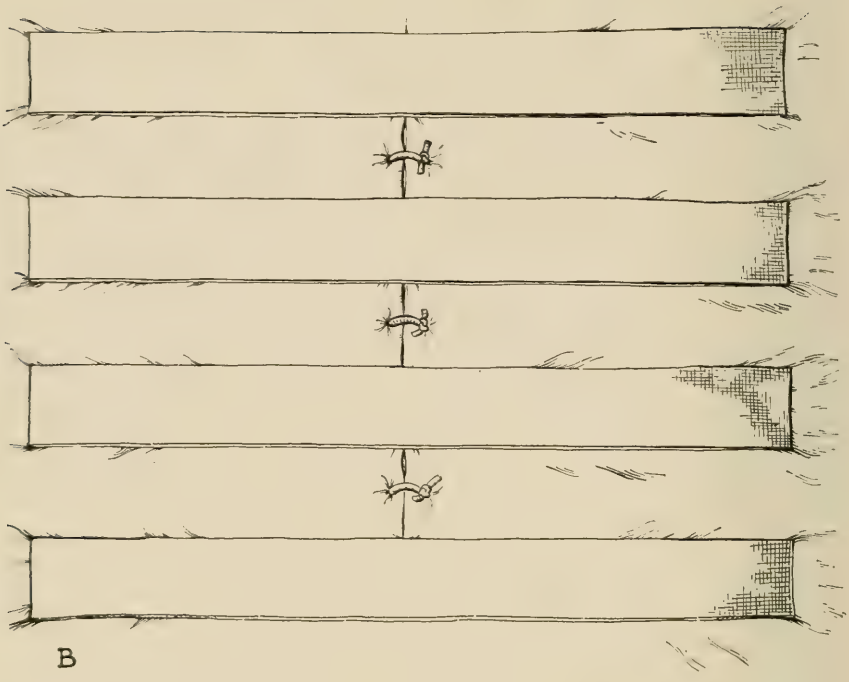
Only aseptic wounds may be closed. Suppurating and infected wounds as a rule must be left open for purposes of free drainage until they become aseptic or protected by clean granulations. Aseptic wounds if left unclosed naturally heal together by some process. Primary healing takes place in some wounds which receive no surgical treatment. Clean incised wounds tend to fall together and heal primarily without treatment. Lacerated wounds of the perineum due to childbirth often do the same. If healing by first intention does not take place the natural process is for the wound to granulate and for the granulations to become covered with epithelium. The surgical closure of wounds is accomplished by several different means. Whether or no a wound shall be closed must depend upon the judgment of the surgeon. Dirty or much infected wounds should not be closed, but left open to drain. Wounds in areolar tissue, such as the palm of the hand, should generally be provided with drainage or left open. Wounds of such vascular tissues as the tongue or face may be closed at once.

A simple compressing dressing or bandage often is all that is required to close a wound and give primary union. Sterilized *adhesive straps* may sometimes be used in closing small clean wounds (Fig. 109).

Another method is to place a strip of adhesive plaster parallel with the wound on either side, and connect the two strips by transverse strips of the same material or by sutures. Adhesive strips provided with tapes to be tied or with hooks for lacing are sometimes convenient (Fig. 110).

The **Michel clamp** is a metallic toothed clip, which is put on with forceps, catching the skin on either side of the wound and drawing it together (Fig. 111). If a small wound is aseptic and dry it may be closed with collodion, over which a layer of gauze is laid and again painted with collodion.

The most satisfactory and commonly employed method of wound closure is by sewing. Like tissues should be sewed to like, especially in deep wounds. Sutures may be interrupted or continuous. The materials most used are catgut, silk, linen, silkworm-gut, silver and horse hair. The **interrupted suture** is passed through the skin about ½ cm. (¼ inch) from



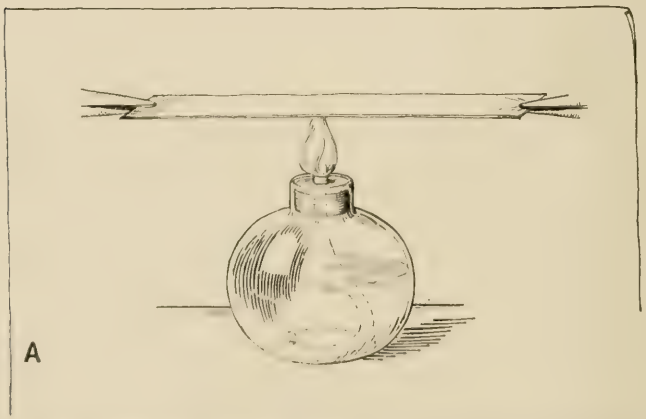


FIG. 109.—STERILE ADHESIVE STRIPS USED TO CLOSE WOUND.

Because of the tendency of the skin to become inverted when only adhesive strips are used it is best to alternate the strips with sutures or clips. *A*, Sterilizing strips over alcohol flame; *B*, strips applied between sutures.

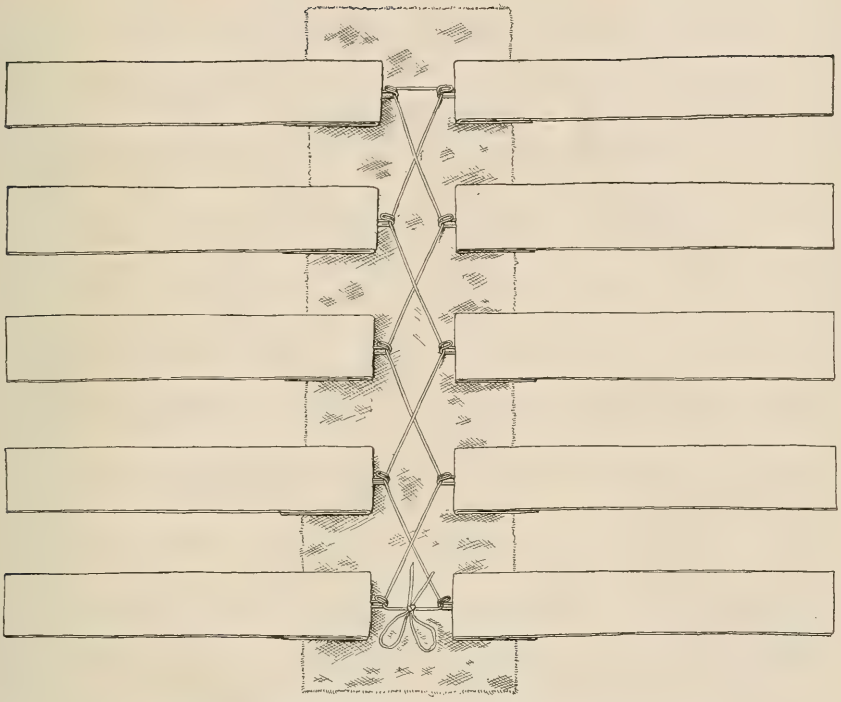


FIG. 110.—ADHESIVE STRIPS WITH HOOKS FOR LACING.
Wound has been sutured and gauze dressing placed over it. Lacing serves to relieve tension, and retain dressing.

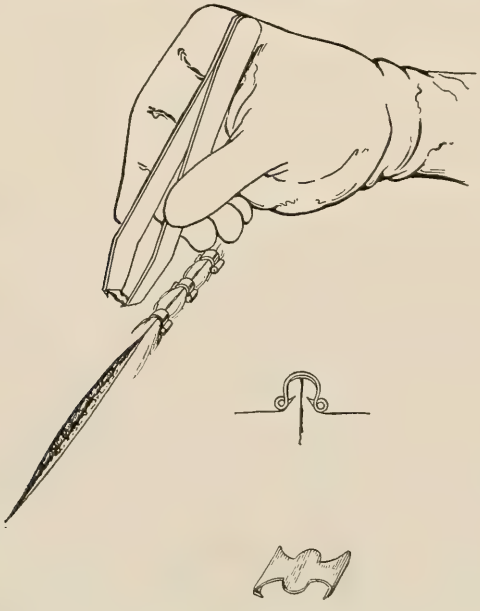


FIG. 111.—WOUND CLIPS USED FOR CLOSING SKIN WOUND.

the edge, well down toward the bottom of the wound, and out on the other side. The two ends emerging through the skin are tied in a square knot to one side of the wound (Fig. 112). The **continuous suture** is applied

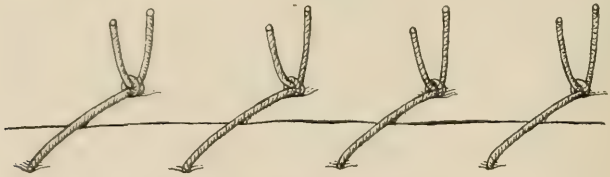


FIG. 112.—INTERRUPTED SUTURE.

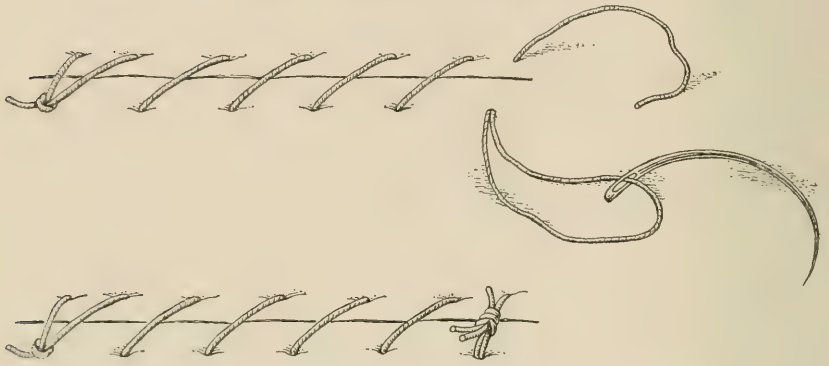


FIG. 113.—CONTINUOUS SUTURE.
Showing method of introducing and tying suture.

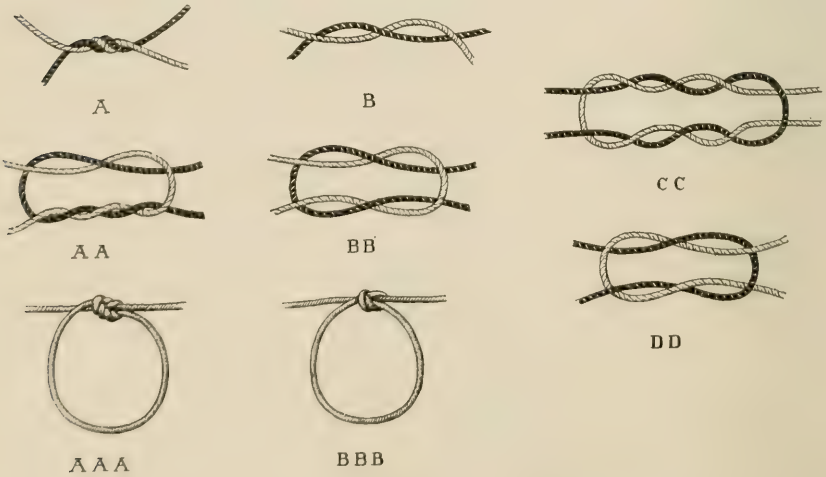


FIG. 114.—METHODS OF TYING KNOTS.

A, Two turns in first half of surgeon's knot; *AA*, two turns in first half and one turn in second half of surgeon's knot; *AAA*, showing same knot pulled tightly; *B*, first half of simple square knot; *BB*, completed square knot; *BBB*, square knot pulled tightly; *CC*, double turn in both halves of surgeon's knot; *DD*, sliding or granny knot.

the same as the interrupted suture except that it is tied only at the beginning and end (Fig. 113).

In tying *knots* to secure either sutures or ligatures the surgeon employs the reef knot (Fig. 114). In order to be sure that a square knot is tied a

practical scheme is to say "to" and "from" as the end of the thread is carried toward and away from the surgeon in making the turns. In tying important knots one and a half or two square knots should be made in order to insure security. The surgeon's knot is the first step of a single knot once repeated and is used to prevent the first turn from slipping when a knot is to be made with some tension. The "granny knot" is to be avoided unless it is desired that the thread shall be allowed to slip. Other knots and sutures are shown in Fig. 63. In order to prevent the first turn of the knot from slipping while the second is tied an assistant may grasp it with the point of the anatomical forceps. The two turns of the surgeon's knot answer the same purpose. For tying the last end of the continuous suture, a loop of thread is drawn out as the last stitch is passed and this is used to make the knot. Coaptation sutures should not be tied too tightly.

FIG. 115.—TYING THREAD IN NEEDLE TO PREVENT SLIPPING.

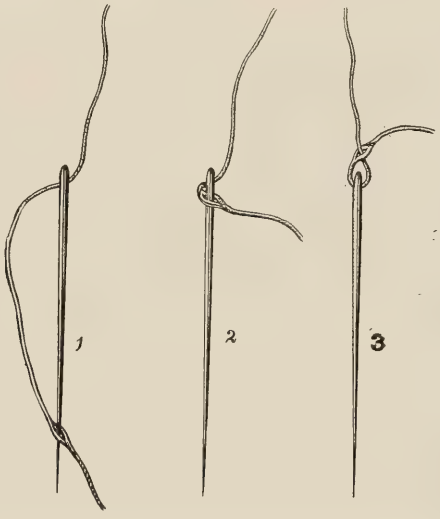


FIG. 116.—PIERCING THREAD WITH NEEDLE TO PREVENT THREAD FROM SLIPPING.

To **thread a needle** most easily hold it with the ring and little finger of the left hand. This leaves the thumb and forefinger free to grasp the end of the thread when it comes through the eye. To prevent the thread slipping out of the needle it may be tied to the eye. This is done in all cases with the ordinary needle excepting when but one suture is to be made with a given thread and in cases in which the smallest possible puncture hole is desired. The thread may be made fast by a single knot (Fig. 115), or, as suggested by F. H. Jett, the short end of the thread may be untwisted and the needle passed through the split thread a short distance from its end (Fig. 116). This expedient is necessary with the ordinary round or oval-eyed needle. A needle is made with a wedge-shaped eye, in which the thread jams into the narrow slit and is there held without being tied. This is much to be preferred (Fig. 35).

There are many modifications of the interrupted and continuous suture. The **buried suture** may be either one or the other of these, catgut being used and the needle not being brought through the skin but only the deeper tissues being sewed, the closure of the skin then being done separately. For closing

the skin in a superficial wound or one in which the deep parts have been united by buried sutures, the **subcuticular suture** (Fig. 117) is to be recommended. It is applied with either a straight or curved sharp-pointed needle, a stiff thread being used. Paraffined linen or silk are good for this purpose. I like to use fine silver wire. The suture is first put through the skin at the end of the wound, and, without tying, is passed in and out from one side of the wound to the other just beneath the skin, and finally out through the skin at the other end. When the two ends are grasped and the suture pulled taut the skin edges are approximated. No tying is necessary. When the wound is healed the suture is cut short at one end and

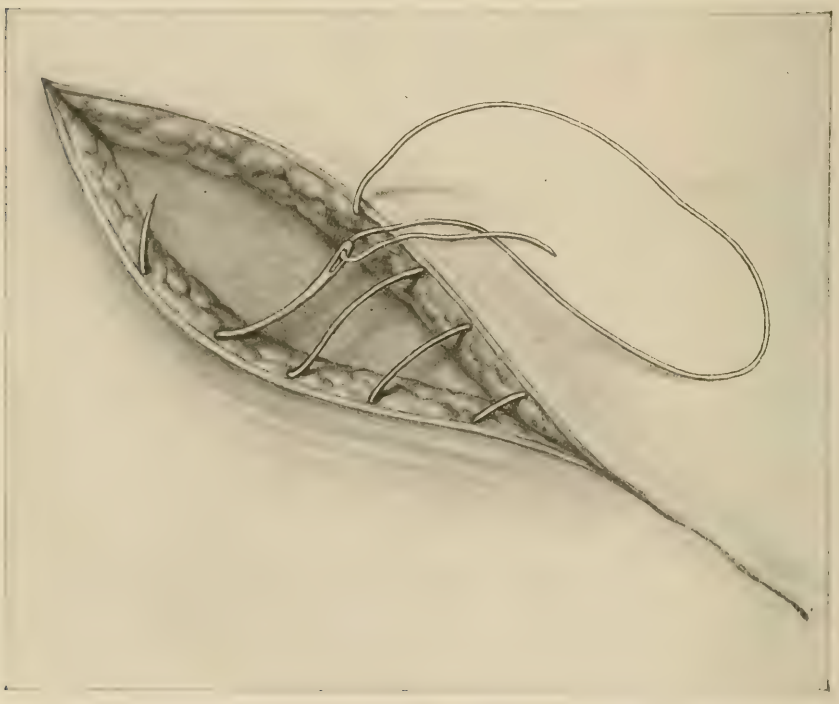


FIG. 117.—SUBCUTICULAR SUTURE APPLIED WITH A CURVED NEEDLE.

pulled out. If desired the wound may be painted over with collodion. If a smooth pliable thread is used and a tendency to gap requires that the two ends of the suture be fixed, a large knot should be tied at the distal end. F. Reder suggested that when the suture has been finished a separate piece of thread or the end of the suture may be tied around the suture in a single knot and then slid down the suture to the skin and tightened (Fig. 118).

In wounds with little tension or but little separation a subcuticular suture of fine chromic catgut may be applied in such a way that the skin is not penetrated at all. It is begun at the end of the wound nearer or toward the right of the operator. A curved needle is passed from within the wound at right angles to and toward the skin, emerging in the wound just beneath the skin. It is then passed just beneath the skin on the opposite side, well back under the skin and down and out in the depth of the wound opposite the point where the suture was begun. It is now tied securely and the end

cut off. This makes a deep suture with the knot downward in the wound. From this point the suture proceeds as a subcuticular suture to the other end of the wound where it is tied in the same manner as at the beginning, the ends cut short and the knot grasped with anatomic forceps and pushed into

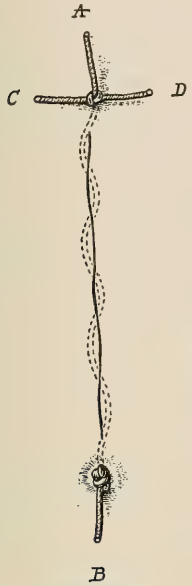


FIG. 118.—SHOWING METHOD OF FIXING THE ENDS OF SUBCUTICULAR SUTURE.

The suture *AB* has a double knot tied at the end *B*; at the end *A* a separate piece of thread, *CD*, is tied about it and down against the skin.

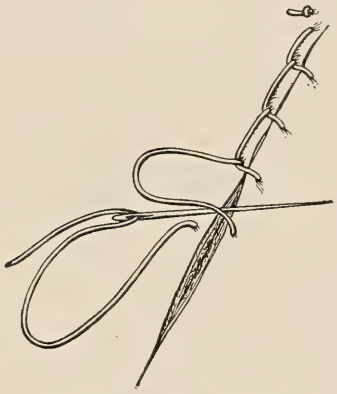


FIG. 119.—CHAIN SUTURE

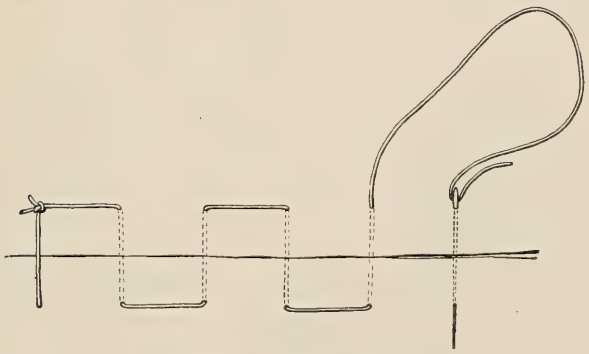


FIG. 120.—MATTRESS SUTURE.

the wound. This closes a wound neatly; no suture passes through the skin; no suture has to be removed; and nothing is to be seen but the line, looking like a scratch, where the skin comes together. The subcuticular suture has supplanted the superficial through-and-through suture where scar is to be minimized. Its advantage is that a wound can be sutured without

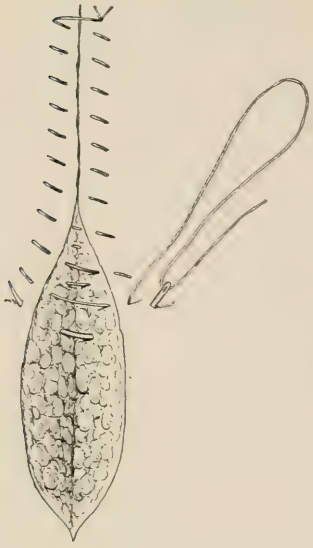


FIG. 120a.—CONTINUOUS MATTRESS SUTURE.

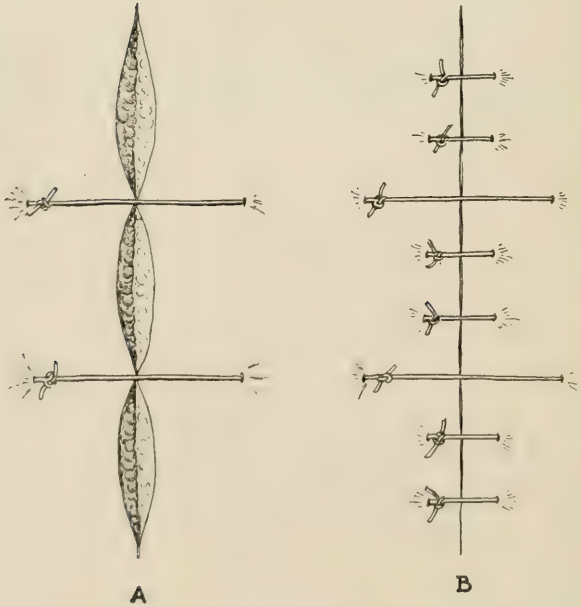


FIG. 121.—RELAXATION SUTURES.

(*A*) The deep sutures bring together the deeper parts but superficial sutures are required to complete the closure (*B*).

involving the skin. The neat application of the subcuticular suture comes with practice. The edges of the skin must be clean cut. If there is a bulging out of subcutaneous fat or areolar tissue it must be trimmed off. Some surgeons seem never able to master it.

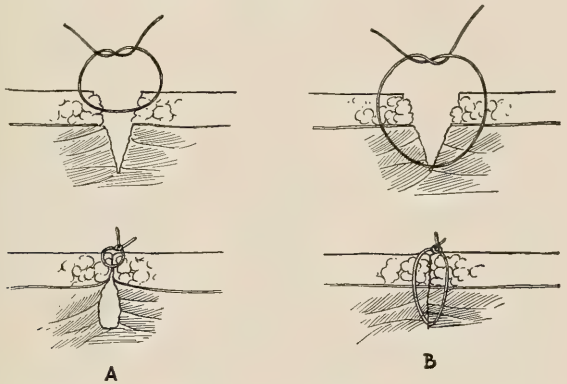


FIG. 122.—SHOWING NEED OF DEEP SUTURES.
A, Wound improperly closed; *B*, wound properly closed to avoid dead space.

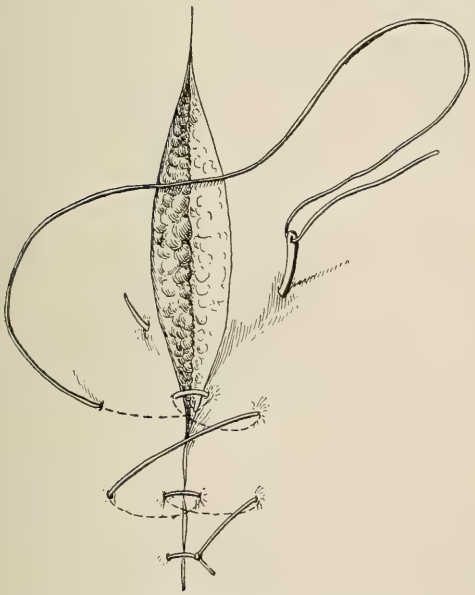


FIG. 123.—SKIN SUTURE IN WHICH ARE COMBINED IN ONE CONTINUOUS OPERATION THE DEEP RELAXATION SUTURE AND THE SUPERFICIAL SKIN SUTURE.

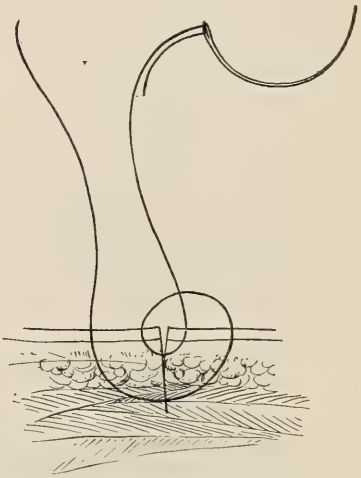


FIG. 123*a*.—COMBINATION CONTINUOUS SUTURE.
This is a continuous suture which provides a deep relaxation suture and a superficial coaptation suture alternately applied.

The **chain suture** is a continuous stitch in which each loop of thread catches the adjacent loop (Fig. 119). It is especially useful in gastrointestinal suturing.

The **mattress suture** (Fig. 120) passes transversely across the wound leaving a loop on either side. It is usually interrupted, but it may be continuous. It may be parallel or transverse (Fig. 120*a*).

Approximation sutures (Fig. 121) may be made to grasp a large amount of tissue and then the skin edges may be held together with **coaptation sutures.** Deep relaxation sutures are needed to close the deep parts of

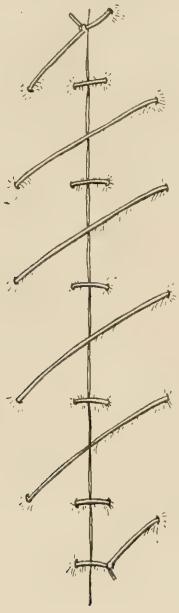


FIG. 124.—COMBINATION SUTURE COMPLETED.

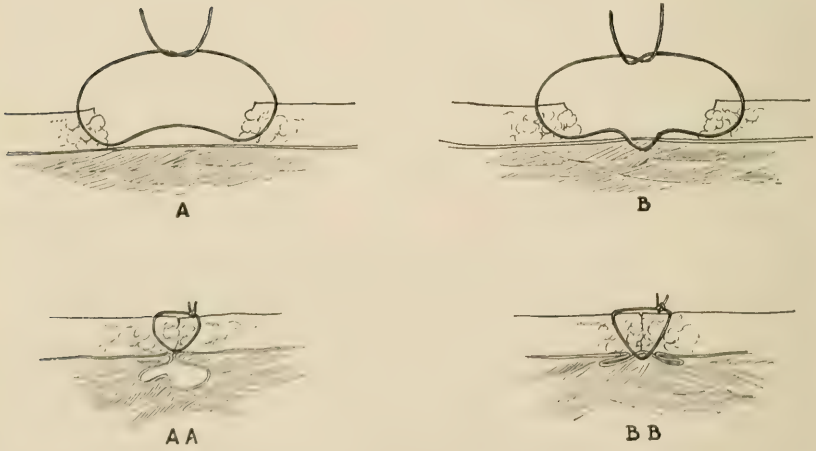


FIG. 125.—SHOWING THE NEED OF INCLUDING DEEP TISSUES IN THE SUTURE.
A, *AA*, Wound improperly closed; *B*, *BB*, wound properly closed to avoid dead space.

wounds (Fig. 122). C. L. Heald (Surg. Gyn. and Obs., xix, 1914) devised a clever combination of the two, applied with the same thread (Figs. 123, 123*a*, and 124).

A single superficial suture should catch the bottom of a broad wound in order to obliterate dead space (Fig. 125).

The **bolster suture** (Fig. 126) is employed in large wounds or to take the tension away from the coaptation sutures. For bolsters, pads of gauze or rubber tubing may be used. The skin should be protected by placing an abundance of zinc oxide powder beneath the bolster. **Pin sutures** (Fig.

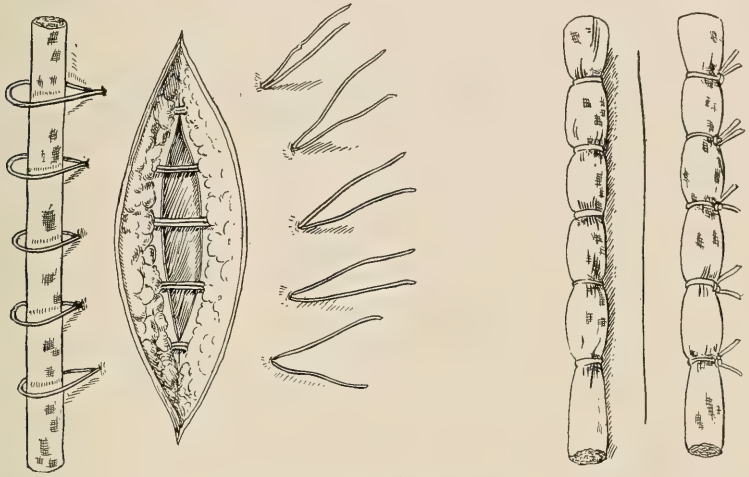


FIG. 126.—BOLSTER SUTURE.
Rolls of gauze are included in the suture loops.

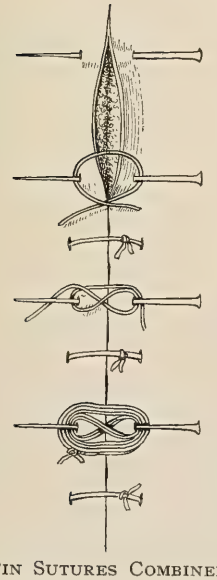


FIG. 127.—PIN SUTURES COMBINED WITH INTERRUPTED SUTURES.

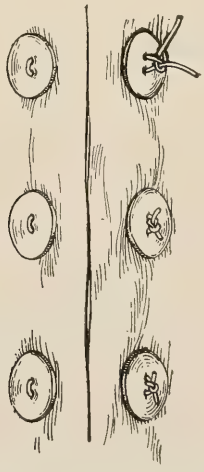


FIG. 128.—BUTTON SUTURE.

127) are quickly applied and consist of a steel toilet pin run through the tissues and wound about with thread. **Button sutures** (Fig. 128) are also used to take up tension, the buttons or beads being made of lead or some other convenient material. Silver wire is useful in these tension approximation sutures.

Continuous sutures may also be applied in the form of the **button-hole suture** or the **shoemaker's suture** (Fig. 129). The **figure-of-eight suture** (Figs. 130 and 131) and the **double figure-of-eight suture** are best made with silkworm-gut, although any suture material may be used.

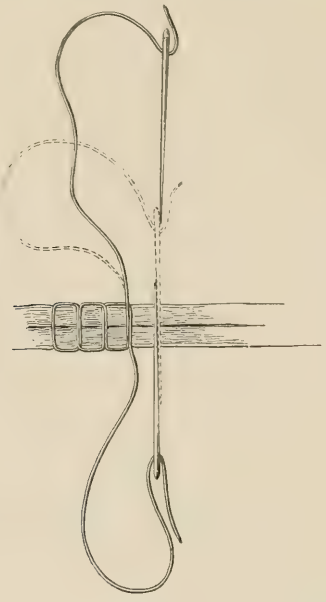


FIG. 129.—SHOEMAKERS' SUTURE, PASSED WITH TWO THREADS AND TWO STRAIGHT NEEDLES.

The use of **adhesive support for tension sutures** was suggested by C. L. Heald (Jour. Am. Med. Assoc., June, 21, 1913), and is applicable in wounds in which there is apt to be much tension, as from vomiting, accidental motion, loss of tissue, or tympanites. Two pieces of adhesive plaster are cut as wide as the wound is long. The end of each piece is wrapped around

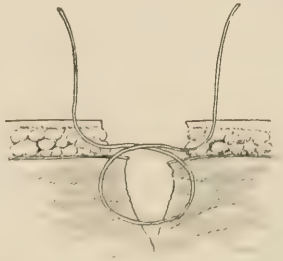


FIG. 130.—FIGURE-OF-EIGHT SUTURE.

a rod of glass, metal or wood (Fig. 132). The tension sutures are inserted in the wound and brought out through the skin with a needle on each end. Each suture is passed through a narrow strip of tape or gauze lying on either side of the wound and parallel with it. The end of the adhesive plaster is sterilized by passing it through an alcohol flame. The plaster is placed on the skin so that the rods lie just to the wound side of the sutures. The

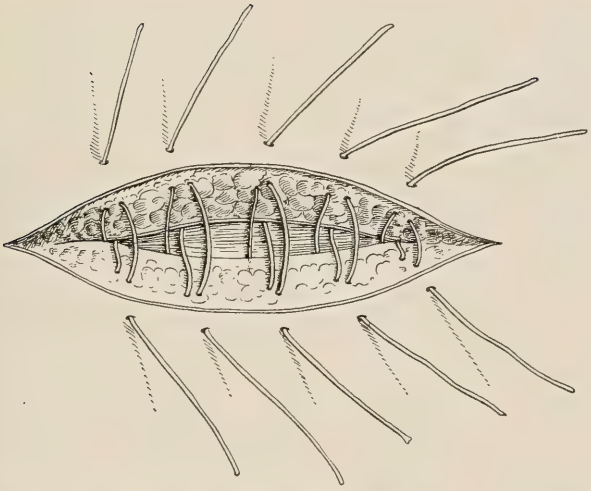


FIG. 131.—FIGURE-OF-EIGHT SUTURE USED TO OBLITERATE DEAD SPACE IN THICK SUPERFICIAL FASCIA.

FIG. 132.—SUTURES PASSED THROUGH ADHESIVE PLASTER TO DIMINISH TENSION ON TISSUES.

A piece of heavy rubber tubing or glass rod is embraced by the adhesive plaster. A pad of gauze is placed between the skin and the tubes

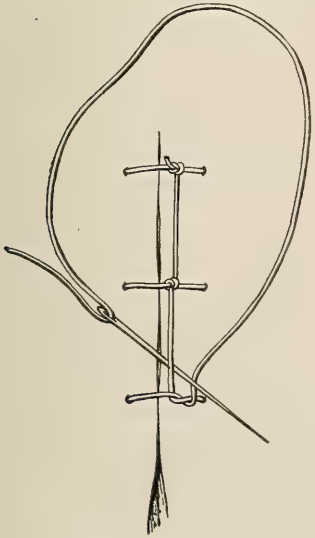


FIG. 133.—TIED CHAIN SUTURE OR INTERLOCKING KNOTTED SUTURE.

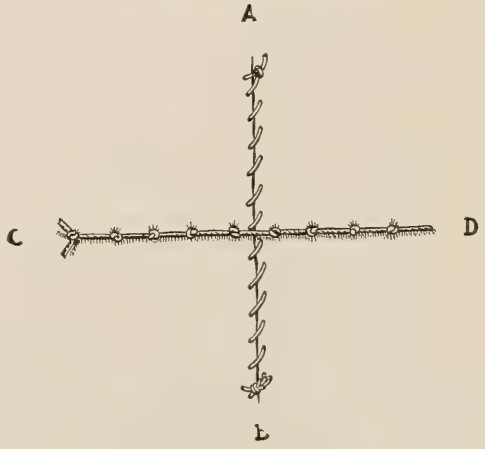


FIG. 134.—INTERLOCKING, CHAIN RELAXATION SUTURE, CROSSING WOUND AT RIGHT ANGLE, TO RELIEVE TENSION.

Tension falls upon several points. *AB*, Wound closed with continuous suture; *CD*, interlocking relaxation suture.

needles, carrying the sutures, are then passed through the plaster, or, what is easier, a puncture is made with a knife and the sutures drawn through this opening, a strip of gauze is laid on the wound as the sutures are tied.

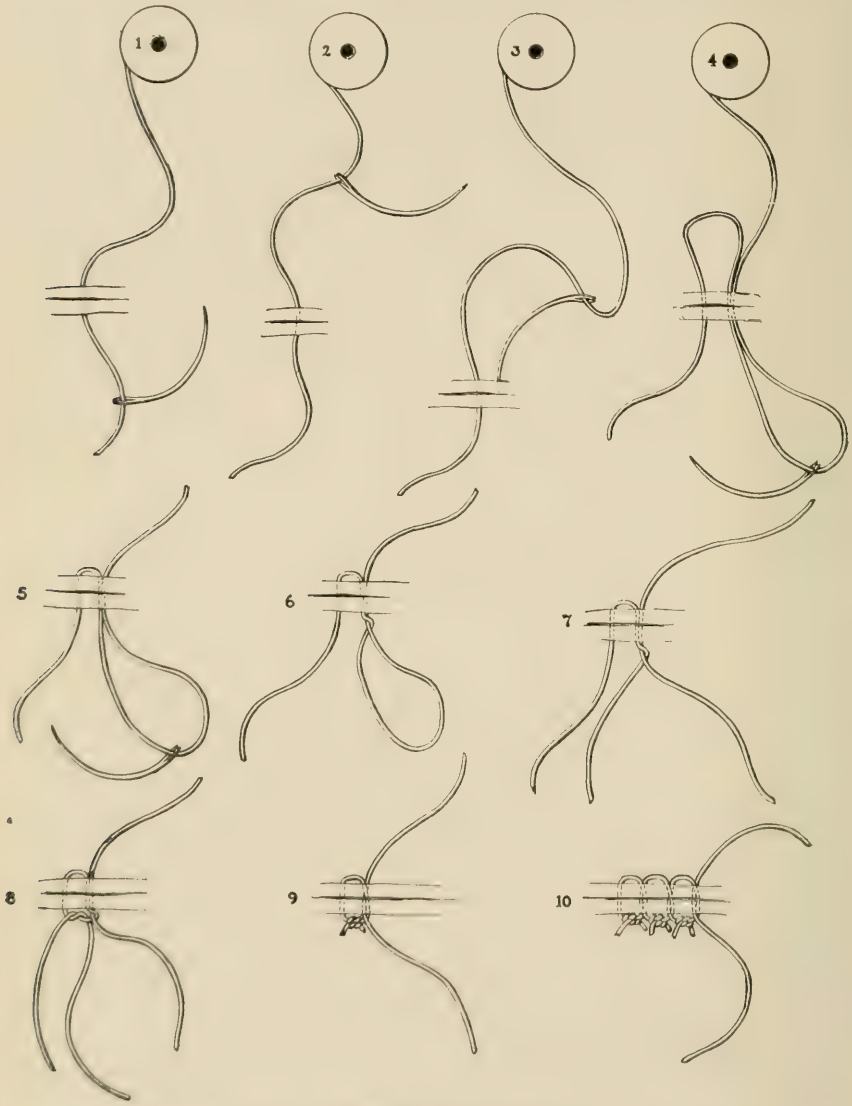


FIG. 135.—INTERLOCKING SUTURE.

Showing series of steps for passing, cutting and tying interrupted locking suture: 1, First suture passed; 2, needle applied for passing loop; 3, passing loop; 4, first loop passed; 5, thread cut; 6, loop rotated, 7, loop cut; 8, first knot tied; 9, double knot completed; 10, result of repetitions of process.

The **tied chain suture** is useful where especial security is desired (Fig. 133).

A **chain suture** for reinforcing the support of wounds with tension was devised by J. R. Eastman (Jour. Am. Med. Assoc., Dec. 31, 1910). Such a suture is desirable after breast amputations and hernia operations. The

tension instead of falling upon two points, as is the case with the ordinary deep single suture, is distributed through a series of attachments. It is applied by simply introducing a suture, tying a double knot, and then introducing another, until a sufficient length has been covered (Fig. 134).

A rapid **interlocking suture,** especially useful in gastrointestinal surgery was devised by Bookman (Jour. Am. Med. Assoc., Oct. 16, 1909). Spring-eyed needles and a spool of celluloid-linen thread are used. If spring-eyed needles are not used a number of needles may be threaded on the strand before beginning. After the first stitch, the thread is brought through the tissues doubled, the loop cut, the previous stitch looped about the last and tied (Fig. 135).

The **purse-string suture** is used for closing round openings and punctures. It is employed especially in closing punctured wounds of hollow viscera, and

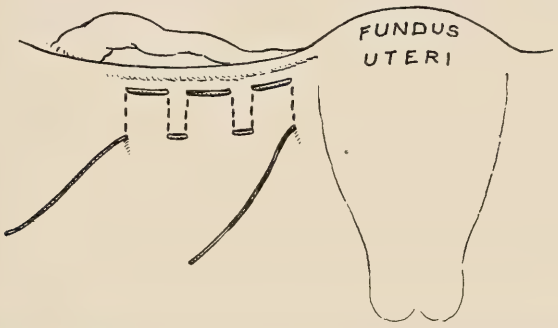


FIG. 136.—INFOLDING, SURFACE-OPPOSING SUTURE, AS APPLIED TO THE BROAD LIGAMENT.

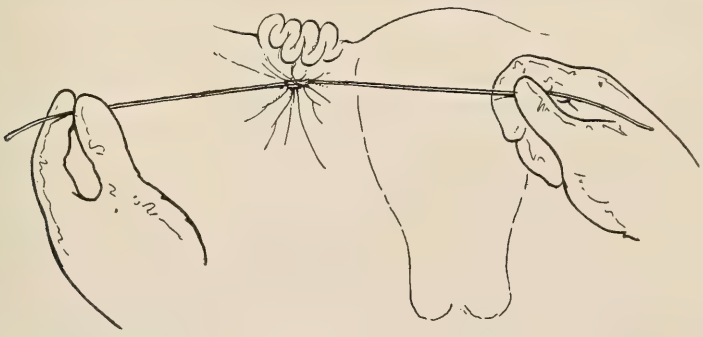


FIG. 137.—INFOLDING SUTURE DRAWN UP AND TIED.

for retaining drainage tubes. It consists of a simple in- and out- running suture placed in a circle around the opening. The two ends are adjacent. When the two ends are drawn upon, the wound is puckered together as the circle tightens. This suture is employed to bury the stump of the appendix after appendectomy (see Appendectomy and Cholecystotomy, Vol. III).

The **infolding suture** is applied especially in the peritoneum for the purpose of securing a broader apposition than is given by the simple running suture. It is used also as a purse-string suture where broad apposition is desired. It consists in inserting a running suture at parallel intervals, the needle being passed in a direction at right angles to the direction in which the tying traction is to be made (Figs. 136 and 137). This suture

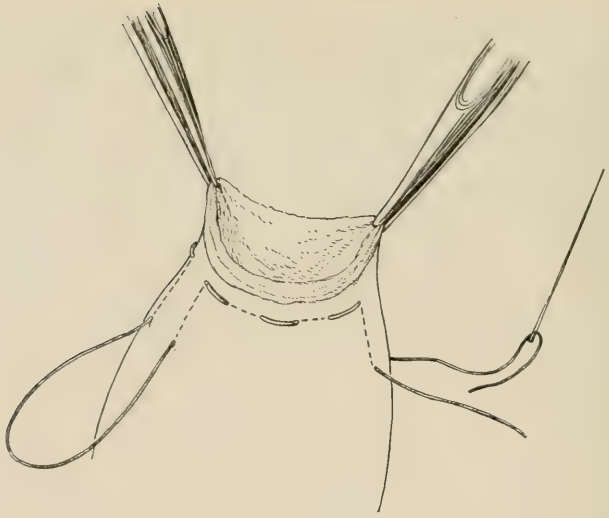


FIG. 138.—INFOLDING, SURFACE-OPPOSING, PURSE-STRING SUTURE AS APPLIED TO THE GALL-BLADDER.

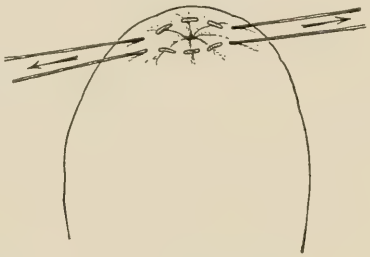


FIG. 139.—INFOLDING SUTURE DRAWN TAUT

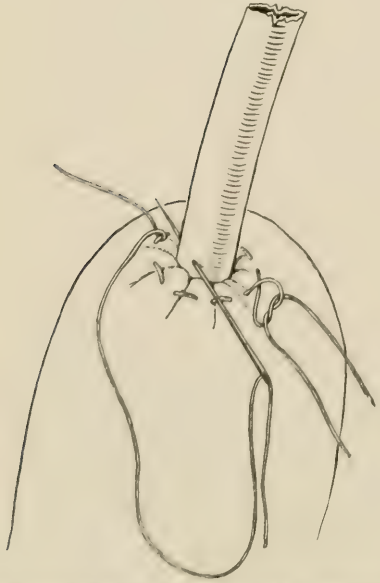


FIG. 140.—INFOLDING SUTURE TIGHTENED AND CATCHING DRAINAGE-TUBE.

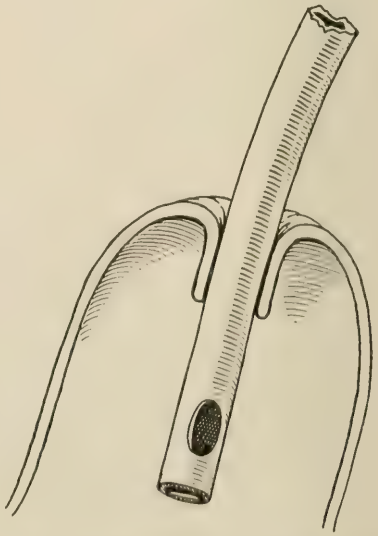


FIG. 141.—INFOLDING SUTURE, SHOWING RESULT AFTER SUTURE IS TIED ABOUT TUBE IN GALL-BLADDER.

is useful for infolding the broad ligament. The same principle is used in closing the opening of a viscus about a tube, as is done in the gall-bladder (Figs. 138, 139, 140 and 141). Similar sutures were described by W. H. Williams and H. A. Shaw (Surg. Gyn. and Obs., vol. xxii, 1916).

A purse-string suture for making the cone in **gastrostomy** or **enterostomy** openings, in which a tube is to be introduced at intervals, may be made obliquely so that it is collapsed against the side of the wall of the viscus. This is done by eccentric application of the sutures (Fig. 142). This operation was devised, by M. R. Bookman (Surg. Gyn. and Obs., vol. xxi, 1915).

In closing wounds, the tendency of the skin edge to invert may be overcome by turning it out with forceps or by coaptation sutures. In order to make a wound which shall leave as little scar as possible, the skin should be cut not at a right angle to its surface but obliquely with a thin sharp knife. The best possible hemostasis and asepsis should be secured. The deep parts of the wound should be closed with fine chromic gut so that the skin falls together without suture. A subcuticular suture is then carefully

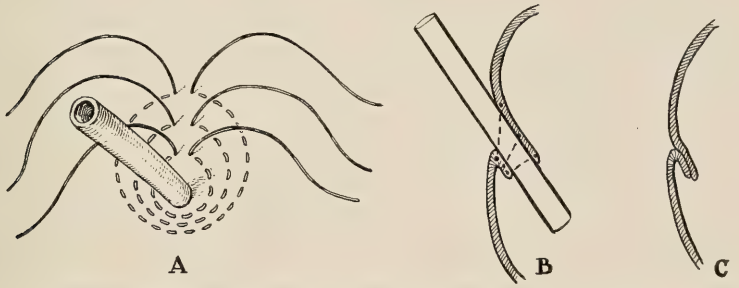


FIG. 142.—ECCENTRIC PURSE-STRING SUTURES APPLIED IN GASTROSTOMY TO PRODUCE OBLIQUE DIRECTION OF FISTULA.

A, Sutures; *B*, tube inserted; *C*, tube withdrawn.

applied with fine silk and a small needle. Over the wound is laid a strip of silver foil, then a few smooth layers of dry gauze tightly held with adhesive strips, and the ordinary dry dressing over all.

The **strengthening of sutures by autoplastic flaps** consists in covering a suture line in the deeper tissues with a flap of fascia, vein-wall, muscle, periosteum, serous membrane, cyst wall, bone, or other structure. This method is applicable especially in operations for hernia, for closing visceral cavities, and in suturing the dura mater.

Tying knots with one hand is an accomplishment which every surgeon should possess. In tying knots, usually one end of the thread is tied around the other. If the twist which ties the second knot is made in the same direction as that which ties the first a "sliding knot" or "granny knot" results; if the second tie is made in the reverse direction of the first a "square knot" is produced (Figs. 143 to 150 inclusive). This knot may be modified by repeating the first half before tying the second half, or by adding a third turn which is a repetition of the first turn. With experience the surgeon soon comes to using only the middle finger to twist the end of the suture about the proximal loop. This method was first well described by G. H. Monks (Ann. of Surg 56, 1912).

Drainage.—All wounds in which suppuration is expected or in which there is apt to be much secretion should be provided with drainage. The best drainage is secured with fenestrated rubber tubing. To prevent the tube becoming displaced it is transfixed with a sterilized safety pin (Fig. 151). After the tube has outlived its usefulness, it should be remembered that its presence acts as a foreign body and so long as it remains in the wound there will be some secretion which its presence excites. Where the discharge is expected to be thin serum, capillary drainage by means of a strip of gauze or wicking is useful. In fresh wounds gauze is indicated where it is

FIG. 143.—TYING KNOT WITH ONE HAND.

The suture has been passed through the two sides of the wound. The needle is held in the right hand. The end of the suture is grasped between the thumb and index finger of the left hand. The two ends of the suture are caused to approach, while middle and ring fingers of the left hand are placed within the loop thus formed, their dorsal aspects lying against the distal end of the suture.

desired to make some pressure. It has the disadvantage that granulations grow into its meshes and its removal is often painful and bloody. Here the cigarette drain is often employed.

In many wounds where only temporary drainage is required one end of the wound may be left open and the rest closed. In certain small wounds drainage can be secured by passing a bundle of horsehairs to the bottom and bringing it out at the end. Wicks made of 75 to 100 strands of the finest silver wire, twisted enough to hold together seem to have capillarity which lasts longer than that of cotton fibres.

Having decided to drain a wound the surgeon should add to the biological principles involved, his knowledge of physics. He will accordingly drain from the lower part of the wound, and if necessary bring out the drainage

through a separate opening made for the purpose (Fig. 152). Superficial wounds usually do not require drainage; but deep wounds, if large, usually do. The surgeon is always on the safe side in employing drainage. The necessity for primary drainage usually shows itself, or has passed, by the end of the second day.

The use of secondary drainage is described under the wounds requiring it. Some points in the introduction of drainage tubes may be mentioned here. To pass a tube to the bottom of a narrow wound or sinus it may be grasped with forceps and have its end bevelled. A urethral endoscope

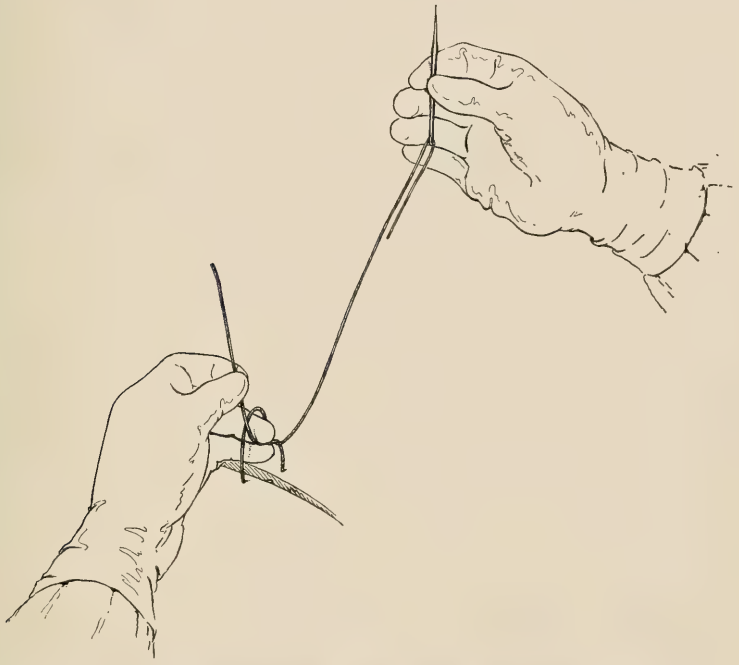


FIG. 144.—TYING KNOT WITH ONE HAND.

The middle finger is sharply flexed, hooks about the proximal part of the suture and draws it toward the palm. As this is done, the distal end of the suture, which is held by the thumb and index finger, is drawn around the tip of the middle finger and held firmly between the middle and ring fingers. All the while the thumb and index finger continue to hold the extreme distal end.

often serves to pass a tube. To secure through and through drainage a long probe may be passed, which carries a silk thread and which in turn drags a rubber tube through.

Dressings.—Dressings are applied (1) to protect the wound from contamination from without; (2) to absorb discharges; (3) to make gentle pressure to control bloody oozing; (4) to act as a splint to immobilize the wound, and (5) to keep the tissues warm and moist, preventing evaporation and cooling, and promoting local hyperemia. Dressings should be aseptic, and, if they are to receive discharges, antiseptic. While plain dry sterilized gauze is much in favor, my own preference is for the moist dressing—sterilized gauze wet with bichloride solution (1:5000). Over this should be placed a layer of sterilized cotton or gauze to keep the environment dry. A dressing

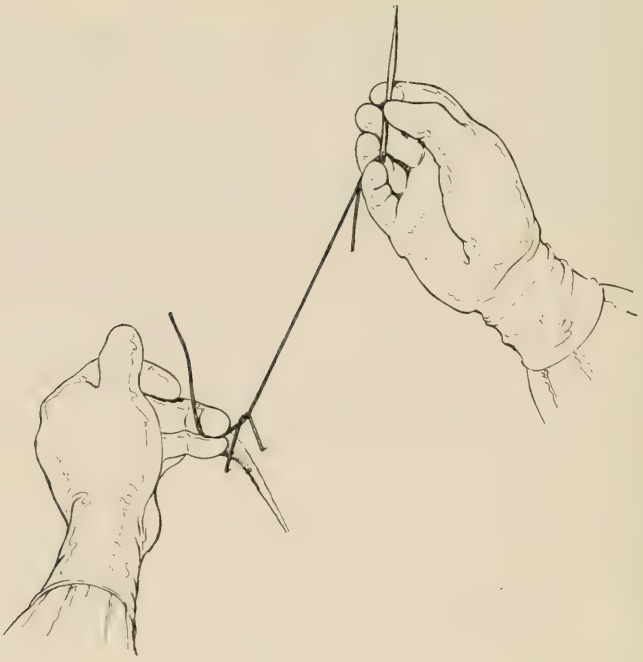


FIG. 145.—TYING KNOT WITH ONE HAND.

The distal end is then released by the thumb and index finger, and traction is made upon the thread as it is held between the middle and ring fingers.

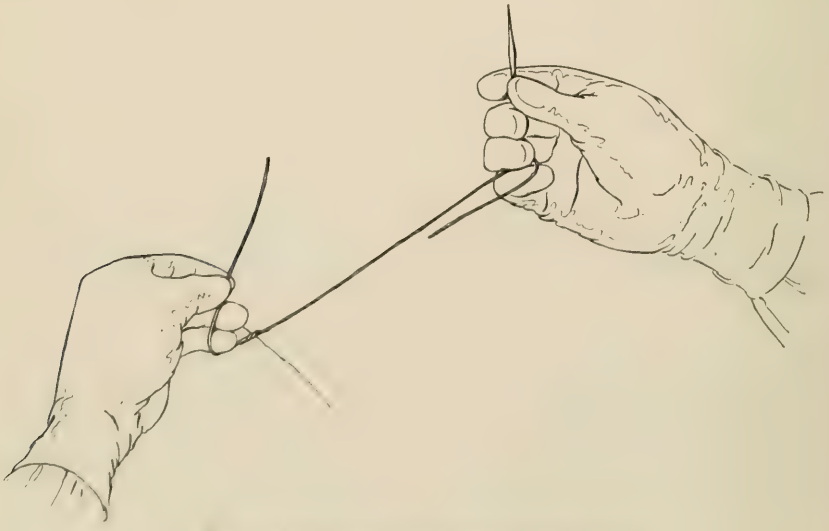


FIG. 146.—TYING KNOT WITH ONE HAND.

The free distal end, having passed through the loop, is again grasped by the thumb and index finger and drawn as tightly as is desired, while the right hand makes traction upon the proximal end. This completes the first half of the knot.

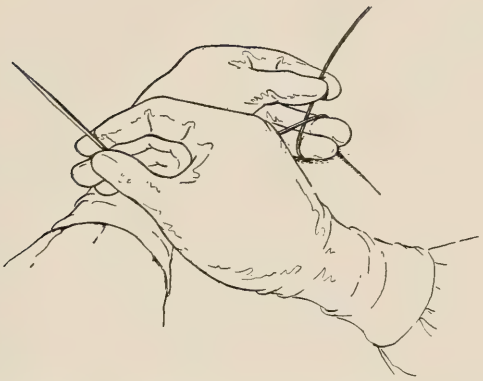


FIG. 147.—TYING KNOT WITH ONE HAND.

The left hand is then rotated so that the backs of the middle and ring fingers rest upon the first half of the knot. The right hand carries the proximal end of the suture toward the left so that it crosses the distal end upon the palms of the middle and ring fingers.

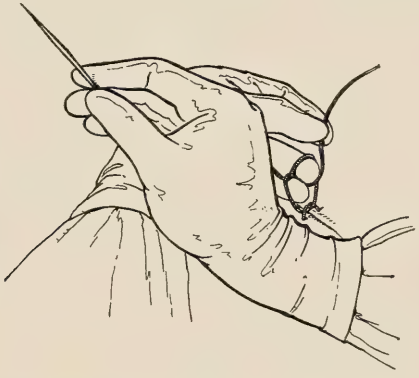


FIG. 148.—TYING KNOT WITH ONE HAND.

The middle finger of the left hand is again strongly flexed as its tip passes between the two parts of the suture lying in front of it. It hooks about the suture and holds it while the ring finger presses the suture against the middle finger.

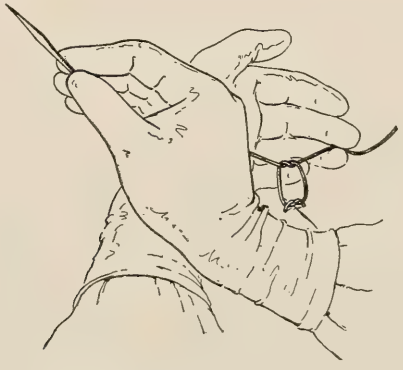


FIG. 149.—TYING KNOT WITH ONE HAND.

The thumb and index finger then release the end of the thread, and the middle and ring fingers, holding it firmly, draw the end through the loop. The proximal end is drawn upon by the right hand carried toward the left.

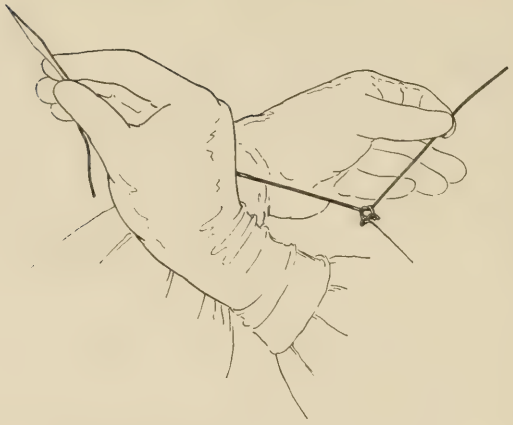


FIG. 150.—TYING KNOT WITH ONE HAND.
The thumb and forefinger again grasp the end of the thread, and continue to tighten the knot.

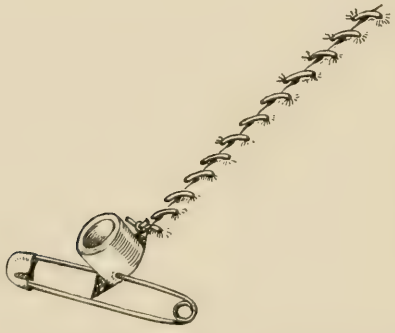


FIG. 151.—RUBBER TUBE IN WOUND FOR DRAINAGE.
Showing pin to keep tube in place. Gauze should be placed between the pin and the skin.

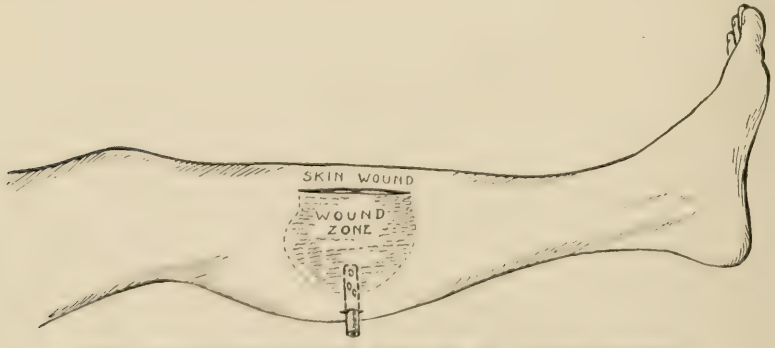


FIG. 152.—DRAINAGE TUBE INSERTED IN COUNTER-OPENING.

should not be too large, lest it be too movable and fail to show hemorrhage if present; nor too small, lest it fail to give adequate protection. For dressing an open wound from which there is capillary oozing iodoform or europhen

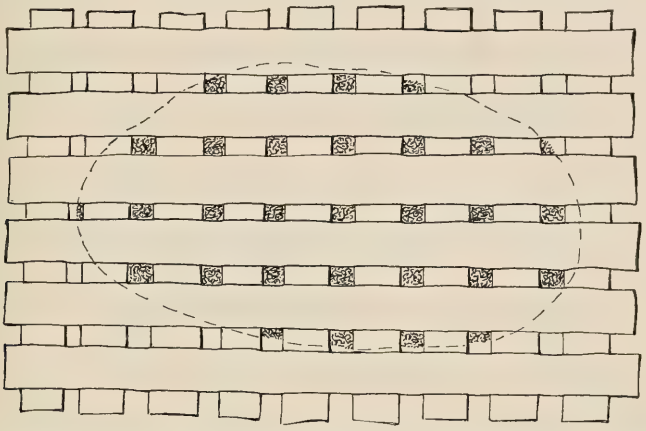


Fig. 153.—Rubber or Oiled Protective Laid on Wound Surface to Prevent Adhesion of Dressings.

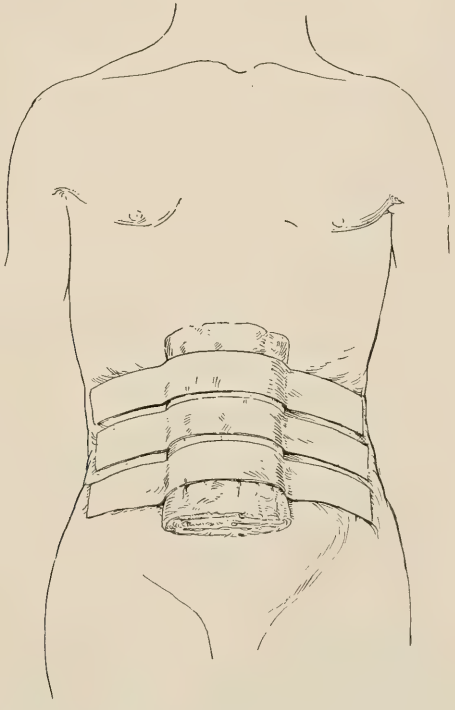


Fig. 154.—Adhesive Strips over Dressing to Hold It Immovable

gauze held against the bleeding surface with some pressure is indicated. Large open wound surfaces, unless badly infected, are best covered with silk or rubber protective laid on in strips with slight interstices to permit the escape of discharges, and the whole covered with the ordinary gauze dressing

(Fig. 153). If gauze is laid upon a raw surface, fibrin coagulates in its meshes and granulations grow into it, so that its removal tears loose much new tissue. Dressings should be held on immovably so that they shall not slide about. If but one dressing is required, as in an aseptic wound, the dressing may be held immovable by adhesive straps (Fig. 154). If there is a prospect of several changes of dressing being necessary, adhesive straps with tapes are of service, permitting the dressing to be tied on without removing the adhesive plaster (Fig. 12*c*). Over the adhesive is applied the regular retention bandage or binder.

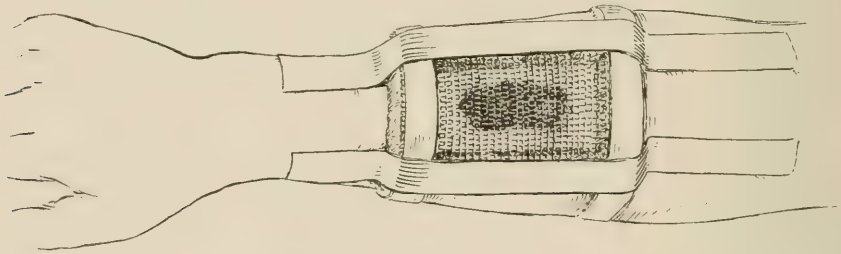


FIG. 155.—FINE WIRE SCREEN USED TO COVER WOUND.
A wall of gauze is placed about the wound and the wire attached by adhesive plaster.

Cotton should not be applied next to a wound as a dressing, nor next to the skin for padding purposes, because its fibres become entangled in the wound, it becomes matted down and poorly absorbent, and it macerates the skin and does not take up skin discharges. Gauze is the most desirable material to place next to the skin. Gauze may be made nonadherent by treating it with paraffin.

The **no-dressing treatment** of clean wounds is applicable to most cases. A sterile operation wound, which has been closed by sutures, does well without any dressing. The danger of (1) contamination from without is pre-

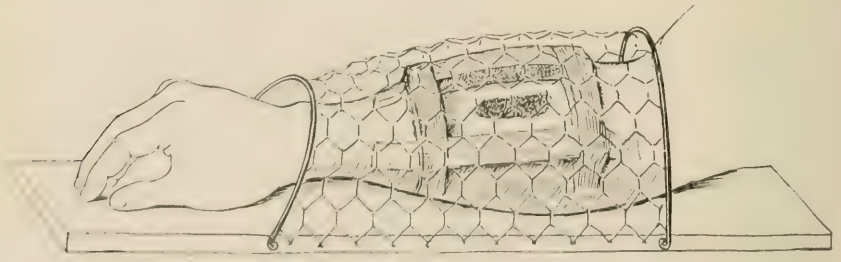


FIG. 156.—WIRE COVERING FOR THE PROTECTION OF WOUNDS.
Ordinary fence wire attached to a splint. The skin about the wound is covered with gauze.

vented by the scab which forms in the line of incision; (2) there are practically no discharges to be taken care of; (3) if the vessels have all been closed and the toilet of the wound well made, there is no bloody oozing; (4) a well-closed wound in a quiet patient needs no further immobilization; (5) the natural state of the tissues without additional warmth or moisture is entirely adequate to promote healing. The reason why dressings are employed in such cases is that they do no harm, and may do good.

If for any reason the surgeon wishes to dispense with dressings, in a wound which does not demand dressings for protection, immobilization or

absorption, the skin should have been sterilized with iodin before the operation. The wound should have been closed with perfect hemostasis, and obliteration of cavities. There should be perfect skin apposition. It will be noticed that a dry scab forms on the wound-line shortly after the suture is completed. This should be painted gently with tincture of iodin as well as the skin on either side of the wound. The painting with iodin should be repeated daily for the first three days after operation, and again after the sutures are removed. A wound, such as follows intramuscular opening of the abdomen, treated in this way, seems to do well. The patient's bed clothes lie in immediate contact with the wound.

For the *no-dressing treatment* of wounds some sort of protection from mechanical injury is often needed. The ordinary wire cloth employed for fly screens may be used to cover small wounds. A square of this is bound with a strip of adhesive plaster, and elevated from the wound by placing it upon two pads of gauze. It is held in place with adhesive strips or bandage (Fig. 155). For larger wounds heavier wire may be employed. The mesh called "chicken wire" is useful (Fig. 156).

Subsequent Dressings of Wounds.—The time for removal of the first dressing and the renewal of wound protection depends upon several conditions. An aseptic wound is healed against infection in twenty-four hours but its surfaces are not firmly agglutinated until the end of a week. After that time non-absorbable sutures may be removed. After the tenth day they are usually of no further service and simply act as foreign bodies. The subcuticular suture is best removed about the tenth day. If it is long, it will come out easier about the fourteenth day. In clean wounds, while there is no necessity for redressing before this, still the patient often feels more comfortable to have the old dressing taken off and a fresh one put on. Closed wounds, with no removable sutures, may be left covered for two weeks, and then all dressing dispensed with. Wounds provided with drainage usually require a change of dressing on the second or third day. This is called for because the dressings are saturated and are beginning to cause irritation of the skin and discomfort to the patient. Gauze dressing or drainage which is adherent to the wound may be loosened and thus removed with less pain by applying peroxide of hydrogen. Subsequent dressings for the purpose of absorbing discharges should be made with aseptic precautions, for, even though there is infection it is not well to multiply the varieties of organisms present. When it is desired that a dressing should remain moist, glycerin may be added or it may be covered with rubber protective to prevent evaporation.

Removal of Sutures.—The sutures should be removed usually at the first dressing of an aseptic wound, which is from the seventh to the tenth day. This operation requires sterilized scissors and thumb forceps, and is discussed in the paragraph above. The surgeon should be sure that he has removed all of the sutures as a single suture unwittingly left behind may be responsible for trouble and blame.

Complications of Wounds

Infection.—After dressing a wound the evidences of infection may appear. These are observed usually by the end of thirty-six or forty-eight hours. The constitutional signs of infection call for an inspection of the wound. Fever and leukocytosis are the important indications. If the infection is deep, often nothing locally suspicious is to be found. The patient should be examined from head to foot, and if no other cause for the fever is discovered, and if the evidences of infection continue, the wound should be

opened under aseptic precautions by cutting a suture and separating the parts with a pair of blunt-nosed scissors or an artery clamp. If signs of acute infective inflammation exist in a wound it should be opened at once. Pus being discovered, the wound should be washed out and a drainage tube introduced. Suppuration developing in a closed wound should be dealt with promptly and radically. It should be freely opened and every pocket drained. If necessary, for the purpose of securing better drainage, a counter opening at some more dependent place should be made. Often it will be best to open the entire length of the wound and treat it as an open or granulating wound.

While infection is present and before the surfaces have become covered with granulations and the wound has become a granulating wound, free drainage is the important indication. Such wounds should be dressed with an antiseptic to check suppuration and hasten granulation. Beside the ordinary antiseptics, one of the best powders for dressing fresh suppurating surfaces is *bitartrate* of *potash* (cream of tartar). If after opening and draining an infected wound there still persist fever and other evidences of continued infection, the depths of the wound should be searched for retained pus. This can be done with the finger or some blunt instrument. After long-continued moist dressings the skin becomes irritated and macerated; this must be met by changing to dry dressings for a while and by protecting the skin with zinc powder or vaselin.

Wounds infected with putrefactive organisms such as occur from dead bodies which have died of streptococcic infection or some pus-producing disease, puerperal fever, septicemia, and from decomposing animal matter, are most dangerous. These include the so-called autopsy wounds and dissection wounds, also wounds received by butchers with instruments soiled with particles of decomposing meat. Cuts of this kind should be encouraged to bleed as the bleeding washes out the infective material. They should then be cleansed with an antiseptic solution, and treated with a chlorin or iodin antiseptic. The wound should then be packed with antiseptic gauze and done up in a copious dressing of the same, covered with rubber protective to prevent evaporation. Cauterizing these wounds is of doubtful expediency, unless the cauterization is thorough and destructive. Punctured wounds of this class should be freely opened and packed. A small amount of arsenic introduced into the wound acts as a powerful antiseptic and vasodilator. Iodin, mercury and the chlorin compounds are the best local antiseptics.

Wounds infected with *staphylococci* require drainage and the ordinary methods of cleansing and treatment of inflammation. Artificial hyperemia is of value (see page 229). Artificial hyperemia is not of value in streptococcus infection. (For a full consideration of infected wounds see Inflammations, page 228; and the Treatment of Infected Wounds, page 237).

Hemorrhage may occur in a wound and be responsible for acute anemia or separation of the wound surfaces. It should be recognized at once if severe (see Hemorrhage). If slight it may only give local signs. A small hemorrhage can be checked by the application of cold and pressure. If the bleeding continues the wound should be opened, the bleeding point found and controlled or the clots removed and the wound packed with gauze tightly enough to stop the bleeding. A small clot developing in an aseptic wound will be absorbed and need not be treated.

Gaping of a wound sometimes occurs as the result of giving way of absorbable sutures or from infection. In the first instance, resuturing is called for; in the second instance, cleansing and drainage must be applied.

Fever, to a measurable degree, is not present in small aseptic wounds, but larger aseptic wounds, especially if they contain much blood clot are associated with rise of temperature due to the absorption of blood ferments. This requires no treatment unless the amount of clot be so great as to interfere with the healing of the wound. If bacteria have infected the clot the wound should be opened and cleaned out. The treatment of wound infection has been described. Malaria, pneumonia, typhoid and other febrile diseases should not be lost sight of as possibilities in a person with a wound, but they should be diagnosed positively before being treated. Fever due to the introduction of instruments in the urethra is best prevented by strict asepsis and by the use of urinary antiseptics before the operation. Hysterical fever should be reckoned with and the hysteria treated. The tonsils should always be examined in seeking for the cause of fever. (Anemia, Thrombosis, and Embolism, as wound complications, are treated in their respective places.)

Shock

Shock is one of the most important conditions requiring treatment in surgery. It is a depression of the nervous system due to stimulation or irritation of afferent nerves, associated with lowering of blood-pressure, vasomotor paralysis, and a conflux of blood in the veins (exemia). There is a loss of venous tone, and disturbance of suprarenal function. Clinically it is similar to hemorrhage, excepting that the blood is not lost, but, if the patient recovers, it is restored to the emptied peripheral vessels. The depression of the vasomotor centres in extreme shock becomes so great that no treatment avails to restore their excitability. Shock is characterized by diminution of the alkalinity of the blood and reduction of temperature.

G. W. Crile believed there were actual physical changes in the brain cells which characterize this condition. This has not been proved to be the case. Still there are certain shock-producing assaults upon the brain which may be inhibited to a large degree. Fear is one of the first causes. It can be prevented by keeping the patient away from frightful influences, and by numbing the association functions of the brain with scopolamin and morphin (see Anesthesia, page 123). Damaging nerve impulses may be blocked and the brain protected by infiltrating the nerves with anesthetic (see Local Anesthetics, page 127; and Novocain, page 136). The use of nitrous oxide instead of ether makes for a diminution in the depression following general anesthesia. Crile estimated that in abdominal operations a patient will endure four times the amount of operative trauma under nitrous oxide as under ether.

Crile applies the term **anoci-association** to this blunting of harmful association impulses; and when this principle is combined with *transfusion* of healthy blood to restore the impoverishment of the blood which occurs in such conditions as acute infections, hemorrhage, intestinal obstruction, peritonitis, cancer, extensive wounds and other depressing chronic diseases, a great reduction in mortality is made possible.

Y. Henderson has shown (Am. Jour. of Physiol., Feb. and Apr., 1909) that shock is associated with a diminished amount of carbon dioxid in the blood (acapnia). More recently it has been shown that shock is accompanied by *acidosis;* and in this condition the ability of the blood to take up carbon dioxid is correspondingly reduced. W. B. Cannon (Jour. Am. Med. Assoc., March 2, 1918) has brought this subject up to date. The two known conditions in shock which can be combated are the acidosis and the lowered temperature.

The prevention and treatment of acidosis (see page 176) the surgeon may control to a large degree. Conserving and restoring bodily heat should be accomplished by wrapping the patient well and applying artificial heat to the surface of the body. When there is a likelihood of pain following an operation it should be prevented.

The **prevention of shock** is of more avail than its treatment. The preliminary hypodermic injection of morphin and scopolamin allays apprehension and tranquilizes the patient. An hour and a half before the operation 0.01 Gm. ($\frac{1}{6}$ grain) of morphin and 0.0004 Gm. ($\frac{1}{150}$ grain) of scopolamin are given. This is repeated an hour later in one-half the dosage, if sleepiness and mental relaxation have not appeared.

For blocking nerve impulses from the field of operation, infiltration of the skin and operative area with 1:400 novocain solution is employed. When the abdomen is to be opened, the peritoneum, not only in the line of incision, but for 2 or 3 cm. (1 inch) on either side, is infiltrated. All large nerve trunks are locally anesthetized. The tissues to be handled where dissections are to be made are also infiltrated. All organs having a sensory nerve supply are blocked. The uterus may be blocked by infiltration of the broad ligament, pericervical spaces, and the round ligament. The vermiform appendix is blocked by infiltrating the mesoappendix; and the gallbladder by infiltrating its basilar attachments.

As the effect of novocain is transient and that of quinin and urea hydrochloride lasts for two or three days, all sensory nerves and the wounded tissues generally are to be infiltrated with the latter in 0.25 per cent. solution before the wound is closed, when this principle is carried out.

The **prevention of pain after operations** is a part of this consideration of shock. Its accomplishment requires attention to all of the details for the prevention of shock. The best mental and physical state should be secured before operation. In compliance with the theory of anoci-association, the lines of incision should be treated with cocain or novocain in adrenalin solution even though the operation is done under general anesthesia; and for the more lasting effect, a sterile solution of urea and quinin hydrochloride (0.5 to 1 per cent.) should be injected into each layer of tissue. This is done with a long needle while the wound is being sutured. The injection should reach 3 to 5 cm. (1 or 2 inches) from the margins of the wound. This solution should not be deposited near the cut surfaces as it interferes with healing. Injected deeply it blocks the traumatized nerves, and insures anesthesia of the wound for several days.

Besides this blocking of nerves the operation should be conducted with the utmost respect for the tissues. No unnecessary traumatism should be inflicted. The comfort of the unconscious patient is also served by attention to the posture. To lie in one position on a hard table for a long period means, pain in the back, shoulders, hips, and heels. A pillow in the hollow of the back and a thick padding between the patient and the table will prevent these discomforts.

The anesthetist should not make undue or prolonged pressure upon any part. The conjunctiva should be spared irritation. (For "gas pains," see Postoperative Treatment, Vol. II.)

Conclusions concerning anoci-association can not yet be drawn because enough information has not been accumulated. We do not yet know what shock is. Whether the use of morphin and scopolamin, and the injection of the nerves and tissues with local anesthetic drugs, which Crile advocates, will stand the test of time we do not know. Surgical opinion is divided. Some say that the theory of anoci-association is the greatest surgical

discovery since the advent of asepsis; and others contend that we must reject both the theory and practice of anoci-association.

There is no doubt but that pain and fear are depressing influences. At least this much we can deal with, and shield patients as much as possible from these two disturbing factors. To Crile more than to any other surgeon, we are indebted for our respect for the nervous system of the surgical patient, and surgeons are protecting it as never before.

Local Protection against Shock.—In operations upon the *head* efforts should be directed to prevent an increase of intracranial pressure. When there is already present such an increase in intracranial pressure, as in tumor, abscess or hemorrhage, it is imperative that the peripheral blood-pressure be not lowered by loss of blood or other conditions. The medulla should be spared traumatism; and for this reason using a mallet and chisel upon the skull is dangerous.

In operations upon the *throat and neck* in the region of the superior laryngeal nerve the patient is to be protected against the cardiac and respiratory depression incidental to irritation of the nerve or its branches. Cocainization of the laryngeal mucosa or direct cocainization of the nerve trunk in operations upon the larynx are of much service in preventing dangerous collapse. Infiltration should be done in goitre operations.

In operations upon the *abdomen*, shock arises from traumatism and exposure of the peritoneum; and the surgeon who traumatizes and exposes the peritoneum the least puts his patients to bed with the least shock. The large splanchnic nerves in the region about the duodenum and diaphragm are especially susceptible to vasomotor depressing influences. The pelvic peritoneum seems less susceptible to shock-production.

In operations upon the *extremities* shock is minimized by saving as much blood as possible, by traumatizing the tissues as little as possible, and by cutting off afferent impulses by injecting the nerve trunks with anesthetic. Spinal anesthesia is of value in amputations of the lower extremities because of the nerve paralysis effected. It should be borne in mind in making amputations that accurate incision should be made. To make a transverse incision producing a flap and then to cut off the end of the flap divides the afferent nerve trunks twice and produces twice the shock-causing irritation that one incision produces. Much trimming and cutting should not be practised; but one clean cut should be made. To prevent shock by "nerve blocking," the main trunks going from the limb should be exposed as a separate and preliminary step, or early in the operation the nerves should be exposed in the wound, and the substance of the nerves injected with a solution of novocain, cocain, eucain, or other anesthetic (see Local Anesthetics, page 127). This procedure is one of the most valuable in modern surgery. It inhibits shock-producing impulses and at the same time permits the operation to be continued with little or no more general anesthetic. As soon as the influence of the local anesthetic has passed, the nerve again transmits impulses; but by that time the patient usually has recovered from the primary danger.

The treatment of shock, when it has not been prevented, demands that the patient shall be handled with the greatest gentleness; wounds and irritated surfaces should be spared every additional irritation. When a nerve trunk coming from the irritated region can be blocked without adding too much to the traumatism it should be done. General anesthesia does not inhibit the afferent impulses; it only inhibits their psychic interpretation.

Lowering the head helps the blood supply to the brain and also to the

lungs and heart. The same thing is accomplished by snugly bandaging the extremities from the toes and fingers upward to increase the volume of blood circulating at the more vital parts. In order to secure elastic pressure, obviate the danger of too great pressure and at the same time retain heat, the parts should be wrapped with cotton and then bandaged evenly with broad flannel bandages. The patient may be given small amounts of hot fluids by mouth. Water or bouillon may be used.

A mechanism for securing even pressure is the *pneumatic suit* of Crile. This is made of a double layer of rubber, which can be put on, laced up, and inflated with a pump. The pressure is even, is made over the extremities and lower abdomen, can be regulated without disturbing the patient, and permits raising the blood-pressure 15 to 40 mm. of mercury. Instead of this, a tight, evenly applied abdominal bandage is useful in increasing the blood-pressure. Bandages to the extremities may be added.

The transfusion of blood from a healthy person to the patient is one of the most valuable expedients in shock. A patient, depressed by disease or injury, who is obviously a candidate for shock, and in whom operation must be done, should be given a dose of fresh blood if possible. This is necessary because the mechanical filling of the blood-vessels is needed, and because as a result of the disease there has been added a cidosis and an actual depreciation of the quality of the blood is present. In such cases the infusion should be done immediately before the operation and again immediately after it (see the Technic of Transfusion, page 348).

When transfusion of blood is not available, other fluid must be used. The objection to this is that all other fluids soon escape from the vessels. There is nothing that takes the place of human blood. Other fluids give some temporary benefit and should be considered. Normal saline solution or colloidal solution is the next resort when transfusion is not available (see Infusion, page 344).

Oxygen gas introduced in the peritoneal cavity at the close of an abdominal operation has been used to diminish and overcome shock. The abdomen can be distended with gas; the pressure upon the diaphragm seems to do no harm. It is possible that what benefit has been observed from this method is due to the pressure upon the veins of the abdomen, and that better results would follow the use of *carbon dioxide* with the oxygen.

Psychic treatment of shock is of importance, perhaps, equal to the mechanical measures. The patient should be given every encouragement. To let a patient in a state of shock be given the impression that he is going to die is equivalent to giving him the death stroke. Patients in this condition should be spared being made the victims of depressing influences. The time to prepare for death is when one is in a sound state of mind and body. The surgeon or friends should display no appearence of anxiety. The patient should be surrounded by as much quiet and simplicity as possible.

Drugs which are of use in shock are few. It is my own belief that *alcohol* and *strychnin* are contraindicated. They produce stimulation or irritation of the vital centres which lasts for a few minutes and contributes to their exhaustion. If at the end of that time something is to take place to maintain the vital powers they might be employed. Thus in slight shock, in which the cause is no longer operative and in which the vital powers are good, there might be some excuse for the use of these drugs; but it is in just such cases that the patient is going to recover anyway in his own good time, and it is doubtful if in the end he is any better for them. *Camphor*, which is a cerebral stimulant, has some value. A 10 per cent. solution in olive oil is used hypodermatically. The dose of camphor is from 0.06

to 1 Gm. (1 to 15 grains). For still quicker action it may be given in 10 per cent. solution in ether.

The patient should be made comfortable, and if this can not be done by mechanical and psychic means a minimum amount of anodyne may be used. *Adrenalin chloride* is of service in shock. Its effect unfortunately is of short duration. If 1 Gm. (15 minims) of the 1 : 1000 solution is added to 500 c.c. of salt solution, and injected subcutaneously, the action is prolonged. Crile has used a continuous infusion of 1 : 20,000 adrenalin solution at the rate of 2 c.c. per minute. Ergot is slow of action but has the power to increase blood-pressure. It may be of value to supplement other measures.

Pituitary extract, made from the posterior lobe of the pituitary body, in 20 per cent. strength, or *pituitrin*, raises blood-pressure, increases the coagulability of blood, and promotes intestinal peristalsis. A dose of 0.5 to 1 c.c. (7 to 15 minims) injected hypodermatically after operation seems to be of value in combating the effects of shock. As much as 3 c.c. (45 minims) are sometimes given.

Pituitary extract introduced into the abdomen, theoretically at least, should meet the indications in shock. W. B. Cannon (Boston Med. and Surg. Jour., 1917) has showed that the relaxation of the splanchnic system, which absorbs the blood into the great abdominal vessels, may be overcome by the local application of pituitary solution. This causes contraction of the smooth muscles of the intestine, and exerts pressure on the mesenteric veins, and thus sends back the splanchnic blood to the circulation.

Conclusions Concerning Shock.—Shock should be prevented by attention to the anoci-association principles of Crile. Fear should be abolished. Psychic and sensory irritations should be prevented. In major operations the nerves should be blocked, nitrous oxide should be the anesthetic of choice if general anesthesia is to be used. Preliminary injections of morphin and scopolamin should be given, and if there is considerable depression or blood poverty transfusion of consanguinous blood should be practised.

It may be said that all of this is difficult and expensive. The answer is, that is the price of success.

The use of other drugs, the pneumatic suit, and restorative measures against cardiac and respiratory paralysis are remote possibilities, the avoidance of which should be the aim of the preliminary treatment.

These special shock-preventing expedients are not necessary in all cases. There are simple operations, in healthy patients, requiring but small wounds, in which the above precautions may be omitted. It is in these cases that ether and other depressing anesthetics may be used and infiltration of the nerves not applied. But even in these cases, as well as the patients seem to stand operation, it can not be gainsaid but that they would have been better off had they been given the benefit of the shock-preventing measures. The older methods often produced surprising and unexpected depression after simple operations.

The depression suffered by patients who were in good health before operation, and the long convalescence which intervenes between operation and complete recovery, may be obviated by the observance of the anoci-association principles of Crile. Surgery has now passed beyond the pathological era, in which surgeons thought chiefly of the pathologic conditions which they were eradicating; it has entered the physiological era, in which the especial attention is addressed to the vital, conserving, enduring forces of the living organism, around about and external to the disease. The new surgery demands that the surgeon shall think not wholly of the mechanics

of removing a disease but more of conserving the anatomy and physiology of the human being which surrounds the disease.

The surgeon should have such perfect control of his operating-room conditions, such mastery of his technic, and should apply the principles of anoci-association so intelligently that he may say conscientiously to every patient upon whom he operates, that, the danger of the operation is less than the danger of the disease. If he can not say this, he is not the master of his art nor of the situation.

Collapse

Collapse or sudden respiratory and cardiac failure, due to reflex inhibition, during operation should be met by discontinuing the anesthetic, lowering the head and elevating the feet, and making rhythmic pressure upon the front of the chest. This pressure serves to produce artificial respiration and circulation at the same time. If respiration does not resume it should be continued artificially (see Artificial Respiration, Vol. III).

Cardiac failure in collapse is usually overcome by the measures already mentioned. If precordial pressure does not restore the heart's action, cardiac massage may be practised. This is especially practicable in abdominal operations: the hand is passed through the abdominal wound up to the diaphragm, and rhythmical pressure made upon the heart from below. Less success has been secured by uncovering the heart by the rapid turning back of a flap containing segments of the precordial ribs, grasping it in the hand and making rhythmical pressure from auricles to ventricles. This operation is justified only in the presence of complete heart stoppage (see Cardiac Massage, Vol. II).

When collapse is complete and there is paralysis of both heart and respiration, artificial respiration should be continued while rhythmic pressure is made upon the heart. Intratracheal insufflation is of greatest value. An intravascular saline infusion should be given. If time can be saved by putting a sharp-pointed needle directly into a vein without dissecting free the vessel, the operation should be done in that way. With the first fluid that runs in 1 or 2 c.c. (15 to 30 minims) of adrenalin solution (1:1000) should be introduced; or the adrenalin may be injected by piercing with a hypodermic needle the lumen of the rubber tube.

Special Wounds

Contusions.—Contusions are of importance chiefly because of the extravasation of blood. Usually this is self-limiting and requires no treatment. To check the bleeding and make the swelling and discoloration as slight as possible, rest, cold and pressure are the best hemostatics. One or all may be used. If ice is applied directly to the skin it will usually stop superficial bleeding in a few seconds. It should not be left on longer than that because of the danger of producing sloughing. It may be followed by a compressing bandage. After a few hours, when extravasation has stopped and the damaged vessels are sealed with clot, the removal of the blood products may be hastened by applying the physiological principles just opposite to those used to check the bleeding. Heat to stimulate the circulation may now be used along with massage. Hot fomentations applied to an ecchymotic skin until its vessels are dilated, and then massage, will hasten most rapidly the disappearance of discoloration.

When the hemorrhage is considerable, as evidenced by tension, swelling and pain, it may be best to incise the hematoma and ligate the bleeding

vessel. Hematomata, resulting from contusions, often are the points of least resistance in which bacteria become lodged and develop into abscesses or other infective foci. This is another reason why they should be cleaned out. Hematomata which are left often result in a cystic tumor having a definite sac which requires to be dissected out before a cure can be affected. Before a sac has formed the condition can often be cured by aspirating the fluid and broken-down blood. In other instances the clot becomes organized into a hard mass in which calcareous deposits occur. This also requires removal to effect a cure.

If the vitality of the soft parts seems to be endangered by a contusion neither cold nor pressure should be applied. Restoration of vascular tone may be accomplished by the careful use of heat and cold alternately. The consideration of contusions of special tissues and regions will be found in their appropriate places.

Incised Wounds.—These wounds are made with sharp instruments. They are the least infected and bleed the most freely of all open wounds. The bleeding should be checked. The skin around the wound should be cleansed. Divided nerves, tendons or muscles should be sutured, and the wound closed. The use of drainage must depend upon the possibilities of infection and the character of the wounded structures. When in doubt, drain.

Stab Wounds or Punctured Wounds.—Punctured wounds, inflicted with pointed instruments, such as daggers, knives, bayonets or slender pieces of wood or metal, are dangerous because of the possibility of injury to vessels, nerves and viscera. The small opening may seem insignificant, when the deeper damage is very great. Slight hemorrhage can be controlled by pressure or packing; if not the vessel must be exposed. If there is no indication of deep injury, the wound should be treated as an ordinary lacerated wound. Punctured wounds should not be closed by suture, because they are apt to be infected wounds, and discharges should have free vent. To probe such a wound can add little or nothing to the information and only carries deeper the infection or introduces it into new channels. In many instances it is wise to insert a drainage tube, particularly if the mouth of the wound involves tense tissue which tends to close it. If gross particles of foreign matter are carried into the wound, it should be laid open and cleaned out. Commonly stab wounds heal without suppuration, but if after thirty-six or forty-eight hours there is an elevation of temperature and other evidences of infection, time should not be lost but the wound should be more freely opened and drained. If it is important to secure primary union in a stab wound, the wound may be excised by an elliptic incision and sewed.

Most of the important stab wounds involve the abdomen, thorax, neck or head, or injure nerves, vessels or tendons. These are discussed under the special regions and structures.

Lacerated Wounds.—When small these wounds require no special consideration: if clean they may be closed; if not, the open treatment is best. Ragged and devitalized tissue should be trimmed away. Often by doing this the wound edges may be made clean and even, and closed like an incised wound. Large lacerated wounds are important because of the shock which accompanies them. If the shock is profound, nerve blocking should be practised in order to discontinue the shock-producing impulses. When this has been done the wound may be cleaned and all possible sources of nerve irritation removed. Nerve blocking has made possible amputation which under general anesthesia alone would increase the degree of shock.

The cleansing of lacerated wounds should be thoroughly carried out. If dirty, irrigation with warm salt solution is advisable. These wounds are contused as well as lacerated, and the amount of tissue which is to become devitalized and slough can not be determined always at the first dressing. Sloughing also depends as much upon infection as upon the mechanical injury and for this reason the best possible asepsis is essential. The wound should be kept warm and free from pressure, and every agency, conserving, vitality should be employed. At subsequent dressings when tissues are found necrotic they should be cut away, and the treatment for sloughing wounds applied.

Wounds with Loss of Substance.—Such wounds are made by accidents which cut out or tear out a certain amount of tissue, leaving the wound open and incapable of having its edges approximated. These open wounds should be cleansed, bleeding checked, and an antiseptic dressing applied. If the surface is small, gauze may be laid upon the raw surface, but if it is large rubber protective or oiled or paraffined gauze into which granulations can not grow should be interposed between the gauze and the wound (see below). Soon the wound becomes a granulating surface and is amenable to plastic treatment or skin grafting. If it is desirable to prevent scar, deformity or save time in the healing of a wound with loss of substance, and the cleanliness of the wound will permit, a plastic operation for its closure may be done at first. This can usually best be accomplished by sliding flaps (see Plastic Operations, Vol. II).

Granulating Wounds.—All wounds not healed by primary union become granulating wounds. Granulations are either flabby or healthy. If flabby they are pale and of slow growth and require stimulation. That is best done by dressing with some of the following substances: balsam-of-Peru 10 parts and naphthalin 1 part; or tincture of myrrh 1 part and water 16 parts; or balsam-of-Copaiba; or castor oil; or alcohol and bichloride solution, equal parts; or tincture of iodin; or some other stimulating dressing. Red and vigorous granulations require no special treatment except protection. They should not be wiped or traumatized in such a way as to provoke bleeding. So long as they are not wounded they do not absorb septic material. Close-meshed gauze spread with zinc oxide or boracic ointment makes a good dressing. If naked gauze is laid upon the granulations they grow into its meshes and bleed when the gauze is removed. If bleeding at the removal of dressings can not be prevented dressing with rubber or oiled protective or silver foil is advisable.

A *non-adherent dressing* which provides good drainage is made by V. A. Dodd (Jour. Am. Med. Assoc., April 18, 1914) by impregnating ordinary white mosquito-net with a mixture of paraffin 2, petrolatum 2, and stearin 1 part. This may be rendered aseptic by adding 0.5 per cent. phenol. One or two layers of this are placed on the wound, and an absorbent dressing over it.

Granulations which become exuberant and rise above the level of the surrounding skin require to be suppressed by astringent treatment. For this purpose burnt alum or silver nitrate should be applied. Silver is used in a 50 per cent. solution on a swab, or for small areas the solid stick of silver nitrate may be rubbed on the surface . If the granulations are very high they should be cut off to the level of the skin with scissors or a sharp knife, and silver nitrate or an astringent powder applied to check the bleeding.

An excavated granulating wound, such as results from an unsutured incised wound, or a granulating wound in which the granulating surfaces may be brought together in apposition, may be treated to advantage by

secondary suture. This is done by rendering the granulating surface as clean as possible and can only be practised with healthy vigorous granulations. There must be no sloughing or necrotic tissue present. All dry skin and scabs must be removed. The surrounding skin should be cleansed as for an operation, and the granulations irrigated with borosalicylic solution. A copious wet dressing of borosalicylic solution should be applied to the granulations and the skin, and changed every day. This should be continued for two or three days. The granulations will bleed some at the removal of each dressing. The last dressing should be a wet dressing of sterile salt solution. The wound is now in condition to be sutured the same as a fresh aseptic wound. When approximated by suture the granulating surfaces become adherent and the wound heals. Sometimes granulations if infected can be gotten into better shape by wet bichloride dressings for a few days prior to the borosalicylic dressings. This is the treatment of granulations which I have found best as a preliminary to skin grafting. Treatment of granulating surfaces with hypochlorite or iodin solutions accomplishes the same result.

Granulating surfaces become covered by skin only by ingrowth from epithelium. Epithelium will easily traverse a distance of 2 or 3 cm. but beyond that the growth is slow except in young children. Therefore, a granulating surface much more than 5 cm. (2 inches) wide is best treated by skin grafting or plastic operation. To hasten the ingrowth of epithelium, the granulations being healthy and not exuberant, a good dressing consists of a copious covering with a powder of stearate of zinc or magnesium mixed with 10 per cent. of subgallate of bismuth. Over this is laid an antiseptic dressing. A clean granulating wound may be dressed every other day. I have treated some of these granulating surfaces with no dressing at all, simply exposing them to the sun or the light of day, and found that they heal faster than when dressed (see Heliotherapy, Vol. III).

Sloughing Wounds.—Sloughing wounds result usually from contusions or from lacerated wounds. They are always infected. Gross sloughs, as soon as they can be recognized as sloughs should be cut away. The wound is best kept sweet by copious applications of balsam-of-Peru. Whenever necrotic tissue is seen it should be removed. Free drainage should be provided. No suturing can be expected to hold in a sloughing wound. If the odor is bad, powdered charcoal makes a good dressing; and irrigations with permanganate of potash or chlorin solution help cleanse and deodorize. Such a wound eventually becomes a granulating wound.

Wounds Soiled with Earth.—These wounds are important because of the danger of tetanus. The high mortality of this disease and the positiveness and harmlessness of the prophylactic use of tetanus antitoxin place the surgeon in a position of great responsibility in treating these wounds. The tetanus bacillus has its habitat in the top soil of the earth, particularly soil under cultivation, and in the dirt of the streets. It is anaerobic and, therefore, develops in deep wounds where it is excluded from the air. Such wounds for its favorable production are usually punctured lacerated wounds, particularly those having some foreign matter or necrotic tissue, giving the organism an opportunity to develop where it is neither reached by the oxygen of the air nor of the blood. Thus punctured wounds made by rusty nails which have lain upon the ground or which are made through the earth-soiled sole of the foot, wounds made by long splinters of wood, blank cartridge wounds leaving cartridge wad under the fascia, compound fractures in which the bone touches the ground, and pitch-fork wounds, are examples of wounds which are prone to breed tetanus.

Such wounds should be freely opened, foreign material removed, the deepest parts exposed to the air, washed with peroxide of hydrogen, and dressed openly. Strong antiseptics or the cautery are objectionable because of the necrosis of tissue which they cause or eschar which excludes oxygen. Tincture of iodin, chlorin solution or pure phenol and alcohol may be used if the surgeon feels that the infection is all within their reach. Often it is best to excise the whole wound area. If this is not done, the patient should be given an immunizing injection of antitetanic serum. This serum is harmless, and it is better to give too much than too little. The minimum dose is 10 to 20 c.c., which should be injected deeply into the muscle of the back, buttock or front of the thigh. To be on the safe side, if there is reason to fear tetanus infection, both the radical treatment of the wound and the injection of the serum should be practised (see Tetanus, page 264).

Wounds infected with the **gas bacillus** are to be given special local treatment (see page 270).

Wounds with Foreign Bodies.—*Bullet wounds* are usually deep, infected, lacerated wounds of small calibre. Their importance depends upon the damage to viscera, vessels, nerves or other important structures. Aside from these the treatment is directed to the infection. This depends much upon the physical condition of the patient. Usually the infection carried in by the bullet is overcome by nature and causes no trouble. If the bullet is lodged in the tissues it becomes surrounded by scar tissue. A bullet not lodged in important structures need not be searched for and removed unless it is very accessible. The object of treatment is to prevent and control infection and not to remove the bullet. The region of the wound of entrance and exit should be thoroughly cleansed and covered with antiseptic dressing. After that, conditions should be met as they arise just as in stab wounds. The necessity for probing a bullet wound is so exceptional that it need not be discussed but rather set down as an unjustifiable procedure. When important structures have been damaged, operation is aimed to repair the harm but not to get the bullet unless incidentally it appears in easy reach during the operation. When important structures have not been damaged, aseptic treatment of the wounds is the chief indication. For locating the bullet, the *x*-ray has proven of such great value that other methods have fallen into disuse. With the *x*-ray available, the bullet probe, bullet forceps and telephonic probe are obsolete. The treatment of bullet wounds of special structures is described under regional surgery.

Shell and shrapnel wounds are treated as bullet wounds, the excessive laceration demanding special consideration. Occurring in men whose skin and clothing are apt to be soiled with dirt and whose nervous systems are oppressed by the psychic influences of fatigue, hate, or fear, these lacerated wounds are prone to do badly. The surgeon should cleanse them, remove foreign matter and devitalized tissues, and treat antiseptically (see Infected Wounds, page 237; and Compound Fractures, page 518).

In all infected wounds with extensive laceration and contusion of tissues, *immobilization* is of much value even though little else can be done. The movements of the parts tend to distribute bacteria into the tissues. Large dressings to make gentle and even pressure, splints to immobilize the adjacent joints and muscles, and recumbent fixation of the injured person, all help to prevent the spread of the infection.

Gunshot wounds, inflicted with bird shot or buck shot, are the same as multiple bullet wounds, unless the shot is superficially lodged, in which event, on account of the chronic induration that it provokes, it should be removed. A similar condition exists in wounds inflicted with *explosive*

bullets. Here the tissues are penetrated by particles of metal of many sizes. It is quite impossible to remove them.

When wounds with foreign bodies become seriously infected they are to be treated by the methods given for treating inflammations (page 237).

The *x-ray in the removal of foreign bodies* in wounds belongs especially to the field of diagnosis, but the operating surgeon may employ it directly as a part of his procedure. The *x*-ray is used as a preliminary to establish the presence of a foreign body. Having done this as thoroughly as possible, if the location is absolutely determined the surgeon may proceed with its removal. It is easy to be mistaken in localization.

Pictures from many positions must be made to guarantee accuracy. A foreign body, it may be assumed, lies outside of a cavity or enclosure

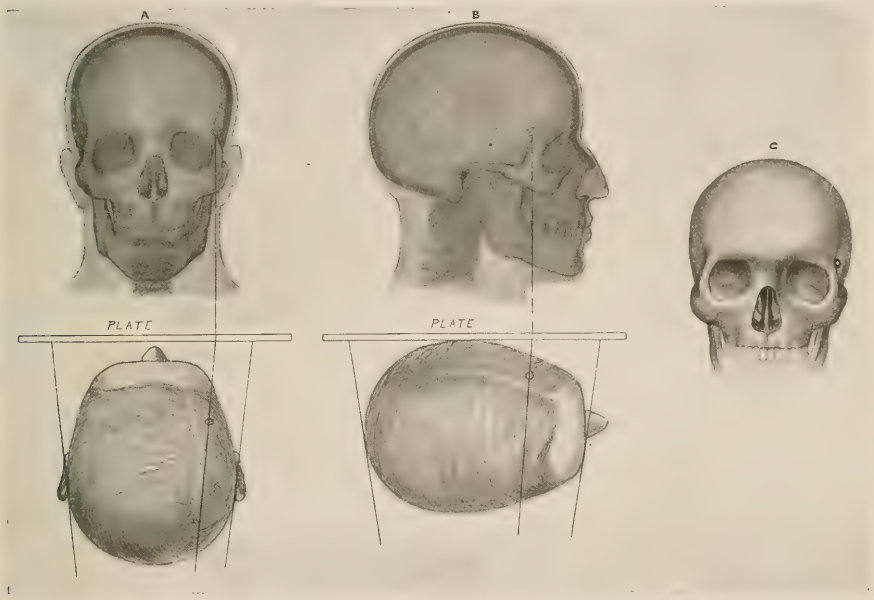


FIG. 156*a*.—BULLET IN TEMPORAL FOSSA.

The *x*-ray seems to indicate that the bullet is within the cranium as shown by both the anteroposterior (*A*) and the lateral (*B*) views. The actual position of the bullet is external to the cranial cavity, lying in the temporal fossa (*C*).

when any picture shows it outside. It is inside of the cavity when no picture from any direction shows it outside. This is the dictum of Holzknecht. It can not be accepted as conclusive because pictures can not be taken from all positions. Two pictures at right angles may give deceptive results. A bullet external to the cranium may be diagnosed as lying within the skull, and a patient subjected to unnecessary trephining, unless skill is applied to the interpretation of the picture (Fig. 156*a*).

By using the geometric principle of triangulation, employed in astronomy, the body may be located. The employment of stereoscopic tubes is helpful. An operating table, having the *x*-ray tube below it, is useful. The surgeon or assistant works with the aid of a fluoroscopic screen strapped to his head. A switch, controlled by the knee or foot, turns the current on and off. A 1-mm. aluminium filter, over the diaphragm, protects the surgeon. The diaphragm should be so small that all of the rays fall within the area of

the screen. With such devices the shadow of the instruments is seen approaching the foreign body. With experience these devices become very helpful.

It must be borne in mind that a body may shift its position very materially between the times of examination and operation. The relaxation of the tissues under the anesthetic often changes the position. A body may be missed because it lies directly under a plain of fascia or is pressed aside by a retractor.

The microphone in the removal of metallic bodies is useful. Especially are pieces of broken *needles* in the hand or foot difficult to locate during operation for their removal. All surgeons are familiar with the numerous cases in which the search for a needle in the pulpy tissues of the palm of the hand or sole of the foot has been given up in despair. The *x*-ray is useful in locating the object, but with small bodies, such as needles, the microphone seems more efficient as a working aid in their immediate removal.

The microphone is an especially sensitive telephone instrument. It has a resistance of 3000 ohms, compared with that of the ordinary telephone receiver which is 75 ohms. A "grounding" is made at one pole with a carbon electrode in the rectum or mouth of the patient. The other pole is connected with knife, needle-probe or forceps. Between the two are the receivers which are applied to the ears of the surgeon. No battery is needed. The current is developed by the moistened carbon electrode in the rectum and the metallic body in the tissues. The presence of strong electric currents near the microphone destroys its efficacy.

After locating the body by the *x*-ray, an incision is made, and the needle at one pole of the microphonic apparatus pushed into the tissues until a contact is secured. This is signalized by a clicking sound which occurs when the contact is made and when it is broken. The knife then cuts down to the point indicated and the foreign body is removed.

Avulsion of Members.—Members, such as a finger or arm, torn out by accident, require the treatment of a lacerated wound. The tendons if not carried away with the avulsed member hang from the wound and require to be cut off. The bleeding is but slight because of the tearing or twisting of the vessels. Large vessels appearing in the wound should be ligated. The main nerves will often be seen hanging free in the wound, in which event they should be cocainized as high as possible and cut off. If there is shock, as there will be if the member is larger than a finger, the cocainization of the nerves and the application of a protective dressing are the important steps. The shock should then receive the surgeon's attention. When that has been overcome the trimming and closing of the wound may be taken in hand.

Self-performed operations (operations performed by the surgeon upon himself) are occasionally called for in emergency and in the event of want of confidence in others. Amputations, circumcision, operations for appendicitis, opening of abscesses, and suturing of accidental wounds have been self-performed. Tzaicon (Rev. Francaise de méd. et de chir., July 10, 1911, and La presse méd., Feb. 11, 1911) operated upon himself for hernia under subarachnoid spinal anesthetization with stovain and strychnin. He reported that the pain of the lumbar puncture is greater than that produced by a subcutaneous injection, but is decidedly less disagreeable than the beginning of chloroform anesthesia. His analgesia came on with agreeable sensations and passed off unconsciously. His intellect was perfectly clear throughout the operation. The only unpleasantness during the operation was slight vertigo when a quick movement was made. The

anesthesia did not go above the level of the crest of the ilium. He sat up and cut into his own flesh as though it had belonged to some one else. The use of his hands was unimpaired. He reached for instruments, washed his hands, and performed all of the functions required of the surgeon in doing so delicate an operation. In reporting this operation, he closes with the statement that a means of anesthesia which is sufficiently efficacious and innocuous to allow the surgeon to operate successfully on himself for hernia without unpleasant consequences may be modified, "but certainly will not be abandoned until human imagination has found a still more wonderful method."

Later Results of Wounds and Ulcerations

Scars.—In order that scars should be as inconspicuous as possible, they should be made to conform to the lines and curves of the skin; perfect apposition should be secured; and the wound should be free from infection, clots and foreign material. These conditions are described under the Making of Wounds. The skin scar may be minimized by provoking a little hyperemia by painting the skin of the wound with tincture of iodin on the third or fifth day after operation. A single application suffices for a small wound in well nourished parts, bnt in a large wound the skin should be treated with the iodin every day for two to five days. Scars which are unsightly or unduly broad may be excised and the wound carefully approximated.

Keloid.—The treatment of this condition of scar hyperplasia is difficult. If it is excised there is a strong disposition to similar hypertrophy in the new scar. If the excision is made far away from the keloid and the latter treated as though it were an infective condition capable of infecting the new wound a cure may be hoped for. Many cases are cured by the *x*-ray. Satisfactory results have been secured by interstitial injections of thiosinamine, 0.06 to 0.12 Gm. (1 to 2 grains), in glycerino-aqueous solution every three days (see Keloid, page 843).

Distortions and Contractions.—Operations for the relief of these conditions are described under Plastic Surgery, Vol. III.

Painful Cicatrix.—Scars are painful when sensory nerves are so involved that they are compressed by the cicatricial tissue. A painful scar may sometimes be softened and the pain relieved by such tentative measures as massage, thiosinamine injections, or electricity; but the most satisfactory treatment is complete excision of the scar, and accurate and careful approximation of the wound. Healing is then secured with a minimum of scar tissue, the nerve has been divided above the seat of traumatism, and a cure is to be expected.

Adherent Cicatrix.—Scar adherent to tendon or other movable structure requires to be dissected free, and measures taken to minimize the reformation of scar (see suture of Tendons).

Postoperative Treatment

After operation the patient should be watched carefully until he has recovered from narcosis and depression. He should not be permitted to become cold. The surface of the body should be made warm by adequate covering and, if necessary, by hot-water bottles. In the use of the latter there is always danger of burning the skin of an unconscious patient and producing a slough unless care is exercised. A shocked or depressed patient shoulb de received in a warmed bed. It is not desirable that a patient should perspire; if he does, the skin should be wiped dry with a dry towel.

Drugs should not be given as a routine, but only administered when there are positive indications for their use.

Pain in the sacrolumbar region, commonly complained of after operation, can be relieved by placing a pillow in the hollow of the back. The best postoperative antiemetic is gastric lavage. Old people should be encouraged to sit up as soon as possible after operation in order to prevent phlebitis and congestion of the lungs.

The occurrence of **postoperative hiccough** indicates the irritation of the nervous system with toxins. Usually this is due to the retention of waste products retained because of faulty elimination. It is so commonly associated with nephritis that the kidneys should always be suspected. It yields to measures to increase elimination and decrease toxic intake Nephritic hiccough should be treated by withholding proteid food and giving plenty of water. A diet of water exclusively relieves most cases.

Intractable hiccough which refuses to yield to the usual measures may sometimes be made to yield to forcible flexion of the thighs upon the abdomen. Abdominal massage or rhythmic traction upon the tongue sometimes gives relief. Apparently desperate cases have yielded to compression of the eyeballs as is done for the oculo-cardiac reflex.

Patients suffering **pain,** should be relieved. It is best that the operation and dressing should have been so conducted as to prevent pain, but if this has not been done the cause of the pain should be sought and relieved, and if this can not be done, morphin to relieve the pain may be given hypodermatically. This should not be necessary after the first twenty-four hours.

For **vomiting** which is due to the ether, no treatment is necessary. After the stomach is emptied and the ether is eliminated the vomiting will stop. It may be prevented by washing out the stomach. Vomiting which persists may be stopped by lavage. An enema often has a good effect.

Dilatation of the intestine with *gas* often requires relief. The less the bowel has been handled and traumatized the less will be the gas distension. Hot water in teaspoon doses, as hot as can be borne, causes the expulsion of gas. This may be due to the expansion of the gas and to the stimulation of the stomach. If the patient sits up he may expel gas from the stomach. A stomach tube will remove it.

The tablets which are much used by the medical profession as "gas eliminants," are to be warned against. They are made of an alkali and acid which produce a large volume of gas in the stomach. They cause the eructation of gas of their own make, which the deluded patient and doctor think is gas of the patient's fabrication. The facts are the reverse of the fancy. The tablets furnish the gas and the patient eliminates it, and he and the doctor are the dupes of another prevalent humbug perpetrated in the interest of business.

The **thirst** which is so distressing after operations may be relieved by giving a little warm water by mouth as soon as vomiting has stopped. In cases in which water by mouth is contraindicated fluid may be given by rectum (proctoclysis).

The **retention of urine** which follows abdominal operations especially should not be permitted to continue longer than twenty-four hours. The bladder should not be allowed to become distended. If the patient can not pass water under the psychic stimulus of hearing running water, a warm enema may be given. As the enema is expelled the bladder will often empty itself. A cold compress over the pubes may stimulate contractions. The patient may be able to urinate by changing his position, lying on his back or turning

face downward. In abdominal cases it is best to support the patient while his legs hang out of the bed and he sits on the side of the bed. In this sitting position he may urinate. Or he may be permitted to stand, if supported on either side. Catheterization should be resorted to as a last measure.

A record of the amount and character of the urine voided during the first twenty-four hours should be kept. Insufficient amount or high specific gravity call for the ingestion or injection of more fluids. The appearance of albumin and casts should be watched for.

The presence of **mucus in the trachea** may be very annoying. In abdominal cases the wound should be well supported with adhesive strips and the patient permitted to cough up the mucus. If there is difficulty in getting rid of it, the patient may be elevated to the sitting position, pressure made on the abdomen, and the mucus coughed up.

In **pulmonary hyperemia,** due to pneumonia or bronchitis following operations, the patient should lie with the head and shoulders somewhat elevated. He should be placed in the fresh air, preferably out of doors, where he should remain most of the day. For the old, elevation of the shoulders is important; for both young and old, fresh air is essential.

Following operations for **thyrotoxicosis** the patient should have quiet, fresh air, and get fluids as soon as possible. Serious cases should have proctoclysis at once after the operation. Morphin may be useful if there is much restlessness.

Other complications, such as **intestinal paresis, hemorrhage, shock, embolism, phlebitis,** and **delirium tremens,** are discussed under their respective heads.

Patients should be given to understand that recovery from serious surgical operations requires time. Abdominal operations are followed by a convalescence which may take the better part of a year, before the patient has attained his maximum resistance.

The surgeon should if possible do a complete operation. No surgeon should think of counting on some fortuitous turn of circumstances to remedy what he has left uncorrected. The wise surgeon assumes that he must be careful, and not depend upon luck to come to his aid. He must do the best that he can for the patient until the patient is well.

INFLAMMATIONS

Inflammation is the reaction of living animal tissue to traumatism or irritation. Surgically this irritation is usually due to bacteria and their products. But there is a condition, not due to bacteria, properly treated under inflammation, and which may be called congestion. *Irritative congestion*, due to the presence of non-bacterial substances, such as antiseptics applied to the skin, requires only that the irritating cause be removed. If the congestion persists, an emollient or evaporating lotion should be applied. *Traumatic congestion*, due to mechanical irritation, such as an aseptic foreign body within the tissues, fractures, or a contusing or irritating force upon the surface, is cured by the removal or discontinuance of the cause. *Hypostatic congestion*, the engorgement of a dependent or pendulous part in the presence of disease of the circulatory organs, requires elevation of the part and correction of the circulatory disorder. Often to this may be added massage or the gentle pressure of a bandage.

ACUTE INFLAMMATION

Acute **infective inflammation** is the condition usually meant when inflammation is spoken of. It is a salutary process. Nature's effort to overcome and remove the irritation should be encouraged, not thwarted. Three things are essential in the treatment: (1) the removal or destruction of bacteria causing the inflammation; (2) the aiding of the body to destroy the organisms which are not accessible to external attack; and (3) the elimination and neutralization of their toxins. Where collections of bacteria can be removed, as in abscesses, emboli or sloughs, they should be removed, and the body saved the taxation of overcoming them or of being depressed by their toxins. "Where pus is, there evacuate" was the old surgical axiom, which still holds good excepting in tuberculosis.

The modern treatment of inflammation may be called the *natural treatment* as it aims to aid the natural efforts of the body. This line of treatment has proved the most satisfactory and generally applicable. It is applied by such expedients as rest, the induction of artificial hyperemia, hot applications, wet packs, nourishing diet, antitoxins, scarifications and incisions. When an abscess has developed it should be evacuated, but the formation of an abscess can often be prevented by appropriate treatment.

The inflammations most commonly requiring treatment are due to infections received through wounds of varying size in the skin, through abrasions too small to be seen by the eye and by internal infections. Wounds which are the seat of infective inflammation may have the inflammation treated by the methods which will be described in addition to the wound treatment already elaborated. Ordinarily the reactions of the body are sufficient to overcome the cause of the inflammation, and no treatment is required. This is the case in the common scratches of the skin and aseptic surgical wounds. Treatment is of value in those cases in which the natural process is slow, the patient absorbing harmful toxins in the meantime; and in cases in which the microbic invasion of the tissues is extending. Here it is important that nature be aided. As a rule no treatment of inflammation should cause pain. Pain and fever are the keys to the situation.

Rest.—The first essential in the treatment of acute inflammation is rest, not only of the part but of the whole body. Motion causes pain, the rupture of fine circulatory channels and the obstruction of local elimination. A patient with a serious infection should be put to bed, and the inflamed part kept as quiet as possible.

Artificial Hyperemia.—This method of treatment was perfected and popularized by August Bier. It aims to aid nature in inducing a local congestion. It should not be used in cases in which there is already an overcongestion as evidenced by tense swelling and cyanosis. Two methods are employed. *Active hyperemia* is an increase of arterial blood brought to the part by the application of heat and other means for accelerating the circulation. *Passive hyperemia* induces an increase in the volume of blood at the inflamed part by obstructing the venous return. A combination of these two is secured by suction. The methods of applying this principle of treatment have been worked out so successfully by Bier that they represent a notable advance in modern surgery.

Fig 157.—Elastic Bandage Applied to Induce Hyperemia of the Arm by Obstructing Venous Return.

For treating infections and inflammations in the limbs a rubber bandage, the bandage of Esmarch or Martin, is used (Fig. 157).

Take, for example, the treatment of a cellulitis of the forearm. The bandage is applied to the arm anywhere between the shoulder and the elbow with just sufficient tightness to impede but not shut off the venous return, and the arterial pulse below the constriction should be palpable. It should cause redness, with possibly here and there blotches of cyanosis, but not a general cyanosis of the forearm and hand. It should cause some swelling. The parts should be warm, not cold. If anything, the affected limb should be slightly warmer than the other. An excess of circulating blood is the object of the treatment. Numbness should not be induced. When the skin is pressed upon the subcutaneous capillaries should quickly refill. The treatment should not increase the pain, but should be expected to diminish it. If pain is increased by the treatment it indicates that an abscess is present, and evacuation of pus is called for.

The bandage should be left on at first for six or eight hours at a time with intermissions of an hour between. If well tolerated it should be left on for periods of twelve hours on the second day, and by the third day it may be applied for twenty-two hours and left off for two hours. It may be left on twenty-two hours the first day if the relief is great. During the two hours of intermission the site of the bandage should receive massage to prevent damage to the soft parts from the pressure. Each time the bandage is reapplied, it should be above or below the place where it was before. Pus should be evacuated when it localizes. In addition to the bandage the inflamed parts may be enveloped in wet dressings. The regulation of

the degree of constriction, which shall not be too great or too little, the surgeon must learn from experience. It is imperative that the bandage should not be left on if it increases the discomfort, causes cyanosis, coldness, numbness, or capillary stasis.

For constriction of the thigh a heavy bandage, that shall not roll but lie flat, is necessary. For the fingers an ordinary rubber band suffices. In order to secure congestion of the shoulder, a rubber tubing, held toward the trunk by bandages, is employed (Fig. 158). The same technic is used as in hemostasis for amputation at the shoulder. Hyperemia of the head is secured by a bandage about the neck; and of the scalp, by a rubber tubing held about the ears. Cellulitis, abscess and carbuncle of the face, neck, and

FIG. 158.—FOR PRODUCING HYPEREMIA AT THE SHOULDER.
A strong piece of rubber tubing is clamped to make a ring. This is held inward by a bandage about the chest and another about the neck.

scalp have been treated successfully by an elastic band about the neck. It need not be tight. But little pressure is required to compress the veins of the neck. Relief of pain is a characteristic result of the treatment. The band may be worn for from twenty to twenty-four hours a day.

For applying suction we are indebted to Bier for a variety of apparatus which may be applied to all parts of the body, and from which the air is exhausted by a pump. The most simple of these appliances are the cups (Fig. 159). They are made of glass so that the condition of the skin may be observed. Various sizes and shapes, to fit different parts of the body, are made. In using this treatment the air should not be exhausted to too great a degree lest the finer subcutaneous vessels be ruptured. Suction is sometimes painful. It can not be applied continuously, one or two sittings a day being sufficient. During each sitting the cup is left on for about three minutes and off for five minutes, this alternation being continued for three-quarters of an hour, thus giving five or six cuppings at a sitting. The cup should rest on sound tissue. The suction should not draw blood.

The cup is of especial value in treating cellulitis, abscesses, and sinuses of the trunk. In abscesses a small opening should be made, the pus drained out, and the suction cup applied. This facilitates the escape of pus and

induces hyperemia at the same time. There is no method which will so rapidly heal an abscess as this. The method is particularly valuable in the

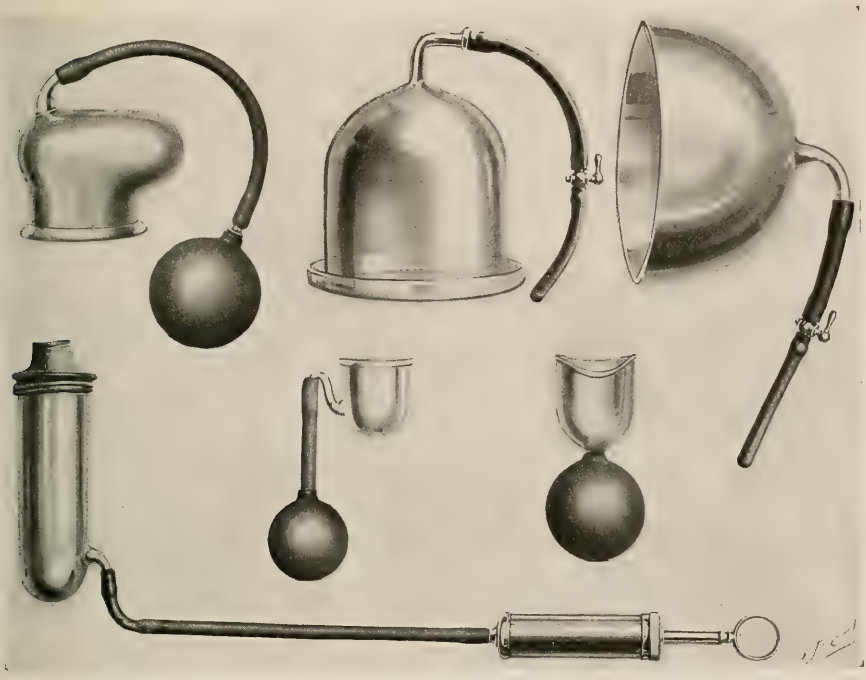


FIG. 159.—SUCTION CUPS AND CHAMBERS, APPLICABLE TO DIFFERENT PARTS OF THE BODY, FOR INDUCING HYPEREMIA.

FIG. 160.—SUCTION APPARATUS APPLIED TO BREAST FOR TREATMENT OF MASTITIS AND ABSCESS.

Pump exhausts the air from glass bell.

treatment of chronic abscesses which are naturally slow of healing, such as found in the female breast (Fig. 160).

For the treatment of joint diseases by suction, heavy glass chambers, closed at either end by cuffs of rubber, are employed (Fig. 161). The suction is applied for five minutes. At the end of that time the stop-cock is turned and air admitted. This is followed by a second treatment of five minutes, and then the air is again admitted. This series of suction and remission is continued for an hour each day. With elastic cuffs, treatment in this apparatus should be painless. This method is particularly applicable to chronic joint diseases with contractures and deformities. The apparatus is so constructed that pressure or traction is made at the same time that hyperemia is induced, thereby moving joints and stretching contractures.

In *tuberculosis of joints* the constricting band may be used. It should be applied for two hours a day, and should be tight enough to cause some edema. The skin should be slightly livid. The treatment should not cause pain,

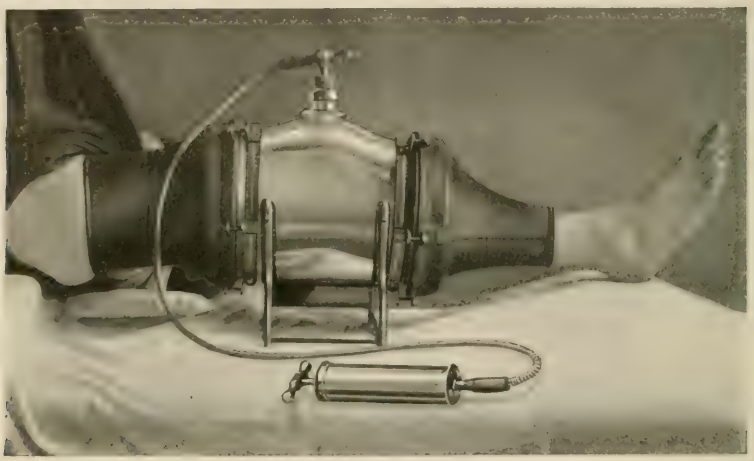


FIG. 161.—SUCTION APPARATUS FOR INDUCING HYPEREMIA OF KNEE. (*After W. Meyer.*)

but should relieve any pain that is present. When tuberculous abscesses appear they should be aspirated aseptically and kept emptied by the use of the suction pump, applied about thirty minutes daily, until the abscess is healed. The constricting band does not interfere with this local treatment. This treatment is best adapted to the hand, foot, and elbow.

In chronic inflammations and sinuses the curative effect of artificial hypermia is most striking. It stimulates the granulation tissue and accelerates the elimination of waste and foreign products. Combined with outdoor hygienic treatment in surgical tuberculosis, it has reduced enormously the percentage of cases requirihg operation. If patients can not wear the bandage all day they may do the best they can; one or two hours a day will make a decided impression upon a tuberculous inflammation. Thus the treatment need not interfere with patient's hours of work.

All inflammations are amendable to this hyperemic treatment; and the ingenuity of surgeons is being dictated to methods for applying it to all locations. A general idea of its applicability may be had by a mention of some of the different conditions in which it is of service. Acute cellulitis, chronic inflammations, tenosynovitis with or witout pus, compound fractures, infected wounds (applied before inflommation has developed), peronychia, periostitis of alveolar process (treated by local suctiin cup or bandage around neck for eleven hours twice a day), fracture of base of skull, furuculosis of face, gonorrheal arthritis, lymphadenitis, mastoid disease, etc. Suction apparatus for the hand is similar to that used for the foot (Fig. 162).

Hot applications are of value in the treatment of inflammation, acting much in the manner of the hyperemic treatment of Bier. Heat may be applied

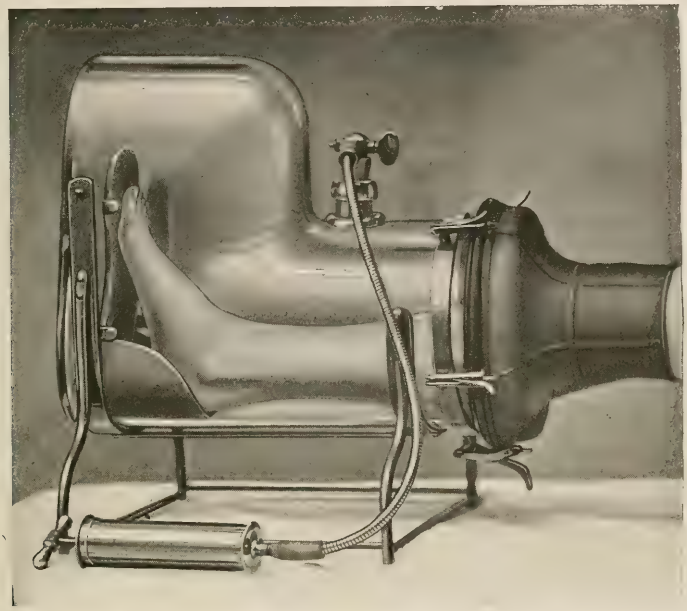


FIG. 162.—SUCTION CHAMBER FOR EXTREMITY. (*After W. Meyer.*)

FIG. 163.—HOT-AIR CHAMBER FOR INDUCING HYPEREMIA BY DRY HEAT, APPLIED TO LEG AND FOOT. (*After W. Meyer.*)

by wet stupes, covered with oiled muslin to retain the heat; hot air by special hot-air apparatus (Fig. 163); or dry heat applied by means of a heated

bag of salt or sand. A good method is to wring out woolen cloths in hot water, apply them, and keep them warm by placing over them a hot-water bottle covered with rubber protective and dry towels.

Wet applications even without heat are of value because, if copious, they cause a retention of the body heat and at the same time tend to increase the amount of fluids in the tissues.

Sterile water, plain water, salt solution, or water containing antiseptics may be used. Saturated solution of **magnesium sulphate** applied in gauze to painful inflammatory affections gives gratifying results. The compresses should be kept wet; they should be covered with impervious protective; and the salt should not be washed from the skin.

Applications of **sea water** from the ocean have the advantage of richness in salts. It is mildly antiseptic, and prevents the progress of infection when applied to wounds. It possesses the properties of a serum. Diluted with three times the amount of pure water it may be used as normal salt solution. When injected as a serum into the tissues of the body it increases the number of leukocytes and is of value in stimulating the natural resistance in inflammations and infections. Taken internally it is a mild laxative, and induces thirst for water.

Poultices are of value for supplying heat and moisture and thus increasing the local hyperemia. Ground flax-seed, made into a mush with water, heated, and enveloped in a flat bag of thin muslin or gauze, retains its heat for a long time and is an ancient method of treating inflammation and one which is worthy of respect. It is useful if no wound exists or is apt to become necessary; but in the presence of a wound it is a breeder of bacteria. The **cataplasma kaolini** of the pharmacopeia is a useful poultice.

Local hyperemia is also induced by the application of **rubefacients** such as oil of mustard, croton oil, oil of cloves, oil of peppermint, oleoresin, capsicum, turpentine oil, chloroform, tincture of iodin, cantharides, etc.

Scarifications, multiple small cuts or scratches through the skin, increase local hyperemia.

The **antiferment** treatment of abscesses, introduced by A. Müller, consists in bringing to the seat of infection an extra amount of the patients' own blood-serum, which in cases of infection is rich in the antiferment bodies which antagonize the infective organisms. The blood-serum is secured by venesection (less than 200 c.c. of the patient's blood is ample) or by serous accumulation developed in vesicles. The skin is touched with iodin, an aspirating needle is inserted, the pus is drawn off aseptically, the cavity rinsed out with warm normal saline solution or serum, and the serum injected into the cavity through the same needle. Serum equal to about one-half of the pus removed is injected into the cavity. This operation may be repeated daily if necessary. An acute abscess may thus be converted into a "cold" abscess (*i.e.*, an abscess in which the bacteria are dead), and the necessity for incision obviated. An abscess containing from 1 to 5 c.c. (15 to 75 minims) of pus heals in about three days. Abscesses holding 30 or 40 c.c. (1 to 1⅓ ounces) of pus heal in ten to fourteen days. The treatment is not effective in abscesses containing more than 100 c.c. (3½ ounces). Gergö claims that normal horse serum gives as good results as autogenous serum. (A further consideration of the vaccines and sera will be found in the chapter on Fevers and Infections.)

Local antiseptic treatment is often of value in inflammations and abscess. The *phenol-camphor* treatment of infected cavities gives good results in some cases. The mixture is made of 35 parts liquefied phenol, 55 parts triturated camphor, and 10 parts alcohol. When injected into an abscess

cavity, this mixture promptly sterilizes the sac. In the early stage of infections of joints and tendon sheaths it aborts the inflammation. By establishing drainage and then injecting 6 c.c. (1½ drams) of this fluid into an infected knee-joint every second day, healing may often be secured after two or three injections. Chlorin solution may be used in the same way.

Abscesses may be treated with pure *ether*. Psoas abscesses, tuberculous abscesses, and carbuncles are amenable to this method. The ether is poured or injected into the abscess cavity and allowed to boil itself away. It acts as a penetrating local antiseptic and stimulant. As much as 45 c.c. (1½ ounces) may be used.

The best antiseptic agents are the iodin and chlorin compounds.

In the early stages of an infection which is superficial, ichthyol ointment (10 to 50 per cent.) applied locally will often effect a cure by inducing hyperemia and by its antiseptic action. Similarly, iodin in the form of ointment; also collargol (15 per cent. ointment) rubbed in the skin. The application of a large wet antiseptic dressing is often of service in superficial infections, combining the advantages of moisture, heat-retention and antiseptic absorption. The hot poultice of gauze, saturated with a solution of boric acid, is one of the most valuable applications.

The **diet** is of importance in the treatment of infections. Two conditions should be considered: the patient should be kept well nourished in order to conserve the vital forces, the production of leukocytes, and the natural antitoxins; and the amount of waste material in the bowel should be reduced to a minimum in order to obviate as much as possible the absorption from the intestine of bacterial products and other toxic substances which depress the vitality and interfere with metabolism. These ends are attained by insuring free bowel evacuations, if not naturally then by the use of injections or medication, and by feeding the patient up to but not beyond the needs of his system with food which represents all of the requirements of the body and which leaves the smallest unabsorbable residuum. Such food is best represented in milk and eggs. To this should be added daily use of the juice or pulp of some fresh vegetable or fruit. Dry bread and butter may be added. Experience has shown that the animal fats, such as found in cream, butter, flesh fat and marrow fat, have the power to increase the number of leukocytes; they are, therefore, of value in overcoming infections. Not an excess but a modicum of food should be consumed by a person lying in bed and doing no work.

Inhibitive Treatment.—The measures which have been described above for the treatment of infections are in a line with the processes of nature to overcome the infective noxa. They have largely supplanted the older methods which may be designated as the inhibitive treatment. The inhibitive treatment looked upon the inflammation and all its concomitants as detrimental and to be combated. For general use it has not a wide application. But there are forms of inflammation in which it is useful. These are the cases in which there is not only an adequate reaction on the part of the body excited by the infecting agents but in which this reaction is excessive. The local heat, swelling and congestion may be extreme and painful, and so exaggerated that to apply artificial means to increase them would aggravate the patient's discomfort and induce local necrosis. In such a condition are found the indications for the inhibitive treatment: cold applications, evaporating lotions, elevation of the part, and counter-irritation.

Cold applications have two effects. First, when cold is applied the blood-vessels contract and the blood-stream in an inflamed zone is accelerated.

This results in carrying off more rapidly the effete products taken up by the blood. In inflammation the blood-vessels become dilated and the blood-stream retarded. If the dilatation is extreme the retardation of the blood-stream may be so great as to amount almost to stasis and there is present a cyanotic condition with a failure on the part of the blood to remove the waste materials. Here the application of cold is salutary. Secondly, if cold is applied to an inflamed area in which there is not an excessive reaction, the cold may have a salutary effect by inhibiting bacterial growth and by paralyzing the vessels, so that when the cold is removed it has actually had the effect to increase the hyperemia. We know that these changes take place; but just where cold ceases to be of greater value than the other contrary methods is not determined. One thing should not be lost sight of, that is, that cold not only effects the vessels immediately under its mechanical influence, but it exerts a reflex action which is transmitted back to the periphery through all the branches of the nerve to which it is applied. Such a

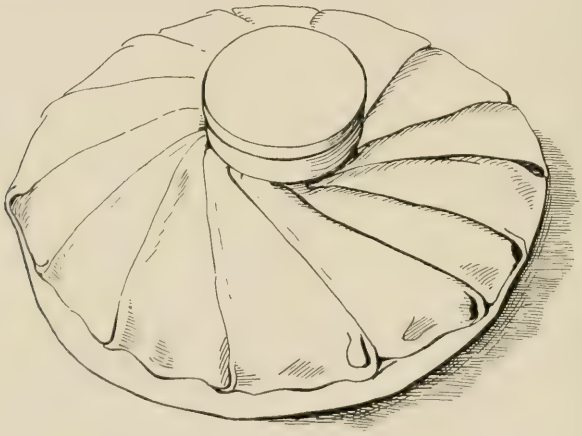


FIG. 164.—ICE-BAG.

reflex action is exemplified in the treatment of appendicitis by cold applied to the abdominal wall. The cold itself does not extend to the appendix, but its reflex influence does.

Cold is best applied in the form of cracked ice, contained in a rubber bag (Fig. 164). A layer of fabric should be interposed between the skin and the ice-bag to prevent too great cooling of the skin. Such an application to an inflamed part causes first a sensation of comfort; if the cold continues, it produces an anesthesia of the skin; and if continued still further, a lowering of vitality is caused which may result in sloughing of the skin. The cold should not cause the skin to become pale or cyanotic but red and congested. When applied to a wound it may be put on over the dressing; although for the cold to be of service the dressing must be very thin. An ice-bag may be extemporized of a bladder or by tying the gathered up edges of a water tight cloth about a large cork or block. The cold water coil, by which water is run through a rubber tubing, is shown in Fig. 165. Cold may also be applied in the form of cold water. An inflamed part is very grateful for being held under a stream of cool running water. A spray of cold water or the old-fashioned capillary drop method are also of service; or the part may be immersed in a vessel of cold water, or cooled by compresses wet with cold water.

Evaporating lotions produce the same effects as cold applications. Any fluid which evaporates quickly has this effect. Alcohol and water are most commonly employed. The virtues of many lotions depend upon this property. A solution made of ammonium chloride and potassium nitrate—15 Gm. (½ ounce) of each to 1000 c.c. (1 quart) of water—is pronouncedly cooling. The virtue of lead and opium lotion depends largely upon the cooling effect of evaporation.

Elevation of the part relieves blood-pressure and congestion by facilitating venous return and impeding arterial supply. Whatever may be said of the advantages of the hyperemic treatment, there are certain painful inflammations of the extremities in which pain is diminished by elevation. This is particularly the case in those conditions in which there is an extreme degree of congestion.

Counterirritation acts by causing congestion in one part and thus removing the blood from another part. It is best applied by combining cold to

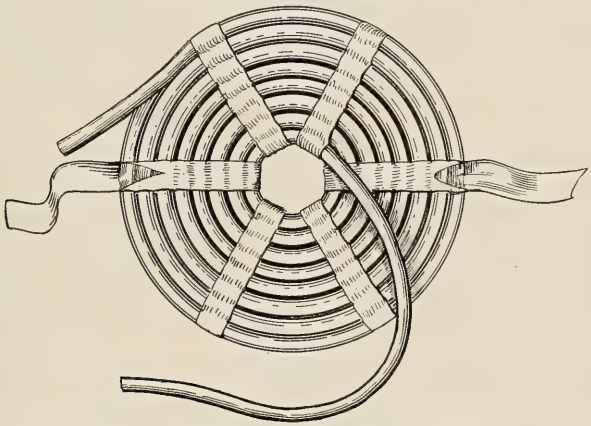


FIG. 165.—WATER-COIL FOR APPLYING COLD OR HEAT BY CIRCULATING EITHER COLD OR HOT WATER.

the inflammation with some means of producing congestion, such as heat, to a region remote from the disease. Thus, in an inflammation of the front of the thigh cold would be applied to the disease and heat to the posterior aspect of the thigh; or in inflammations of the head the lower extremities would be treated with hot applications. What is ordinarily called counterirritation should not receive that designation. To apply iodin or mustard to the skin over an inflamed deep part, if the two are supplied by the same nerve, does not draw the blood from one to the other, but dilating the vessels superficially reflexly produces congestion in the deep part, just as conversely deep congestion produces reflex superficial hyperemia and pain (see Rubefacients, page 234).

INFECTED WOUNDS

The treatment of infected wounds requires that all of the vital forces of the patient shall be conserved. Free escape of discharges should be provided. The principals for aiding nature, which are employed in combating inflammation, should be applied (see Infected Operative Wounds, page 211, and Inflammations, page 228).

All the attentions which are given to a fresh accidental wound should be applied (page 186). A suppurating gaping wound should be provided

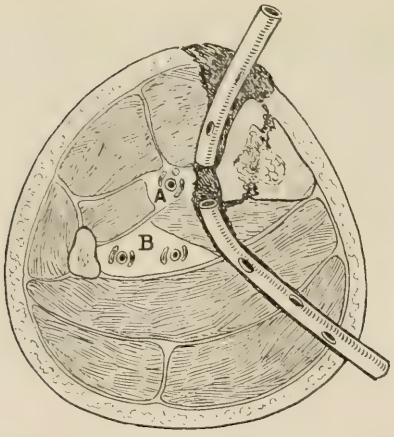


FIG. 166.—SHOWING DRAINAGE OF INFECTED TIBIAL REGION IN MIDDLE OF LEG, SUCH AS OCCURS IN COMPOUND FRACTURE OF THE TIBIA.

A, Anterior tibial nerve and vessels; *B*, posterior tibial nerve and vessels.

FIG. 167.—SHOWING DRAINAGE OF INFECTED FIBULAR REGION IN MIDDLE OF LEG. SHOWING RELATION OF DRAINAGE TO FASCIAL PLANES.

A, Anterior tibial nerve and vessels; *B*, posterior tibial nerve and vessels.

with free drainage. Pus should nowhere be confined under pressure. Deep suppuration should be exposed by enlarging the wound if necessary, or reaching it with drainage tubes. The tubes should be inserted so that every nook and corner is drained (Figs. 166 and 167).

If undrained pus is present or coagulated lymph, the wound should be cleansed by irrigation. For this purpose there are two plans of treatment. Each is effective. Surgery has not yet determined to relinquish either. One is the physiologic treatment, the other is the antiseptic. Drainage is essential in each (Figs. 168 and 169).

The **physiologic treatment** of infected wounds consists in attempting to do what nature is doing. Keeping the part quiet, applying nothing that is

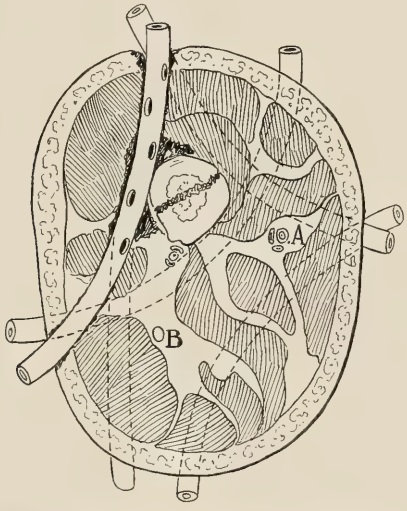


FIG. 168.—SHOWING POSSIBILITIES OF DRAINAGE IN INFECTION OF THE THIGH, SUCH AS OCCURS WITH COMPOUND FRACTURE.

A, Femoral vessels and nerve; *B*, sciatic nerve.

irritating, and removing discharges are the physiologic indications. Irrigation should be done with normal salt solution. This may in the cases of seriously infected deep wounds best be applied continuously. By placing rubber tubes, which are provided with many lateral openings, into every crevice and pocket, and running through these tubes a constant stream of salt solution, the best is being done to aid nature in removing the infection. When this treatment is applied, the limb or part should be left without dressings, and should be placed over a tub or basin to receive the outflowing water. Simple sterile, warm water, containing a teaspoonful of table salt to the pint suffices.

If the condition does not require such active treatment, once or twice daily irrigation with salt solution, and exposure of the open wound to the light of the sun or electric lamps may be practised.

In wounds not badly infected, and in which a dressing is more convenient than open treatment, after preliminary cleansing, packing the wound with gauze, saturated with normal salt solution, gives good results.

A solution for irrigation and dressing which is aimed to promote osmosis, kill germs, and furnish nourishment for the tissues was devised by *Schiassi* (see page, 58).

The **open treatment of infected wounds** is applicable to superficial wounds, wounds with loss of substance and ulcers. As dry gangrene is much less destructive than moist gangrene, so is a dry wound less destructive. A gauze dressing, held on by bandages, is by no means an ideal application for infected wounds. The growth of bacteria requires moisture and this is precisely what such a treatment provides. Gauze, soaked with pus, pro-

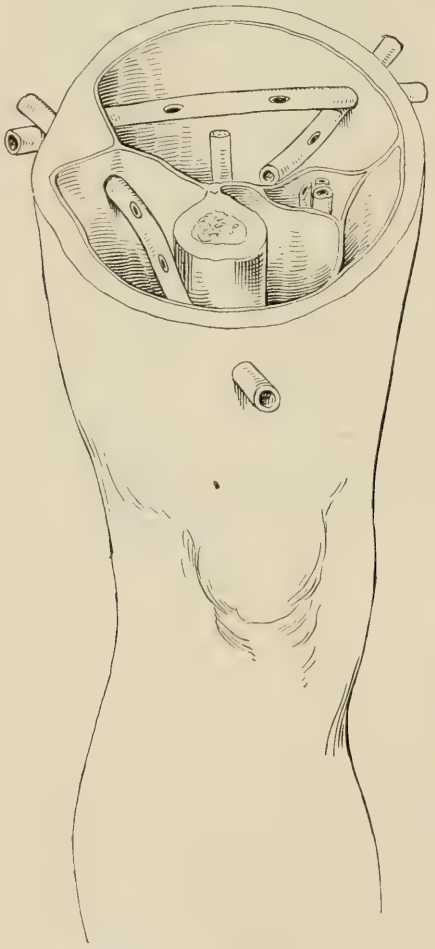


FIG. 169.—SHOWING DRAINAGE IN INFECTION OF THE THIGH IN RELATION TO PLANES OF FASCIA.

duces more bacteria and more pus. If a wound surface can be kept dry, the growth of bacteria is inhibited. This may be accomplished by leaving off dressings and exposing the wound to the air. It is surprising to see how much better an ulcerated surface does if kept uncovered. The small amount of secretion dries and bacteria disappear. By covering the part with a wire cage, the surface is protected from physical injury.

An advantage of the open treatment of fresh accidental wounds is that the tetanus bacillus and the gas bacillus are less apt to develop than in wounds from which the air is excluded.

The **hypertonic treatment** of wounds is carried out by irrigating and dressing with copious quantities of saline solution having a specific gravity greater than that of blood-serum. This causes an exudation of serum. A current passes through the tissues and out into the wound. This current of serum washes out the bacteria and brings leukocytes and antibodies. It is of value in certain wounds which can not be cleansed or dried, and in wounds surrounded by a zone of cellulitis. The hypertonic salt solution of A. Wright is made of sodium chloride 3 parts, sodium citrate (to render the lymph incoagulable) 1 part, and water 96 parts. The citrate may be omitted. Ordinary sea water is equivalent to a 2.5 per cent. salt solution. In dry hard wounds in which infection is penetrating the tissues a 10 per cent. salt solution may be used. The double result of hypertonic solutions is that serum comes out of the tissues and salt from the solution penetrates the tissues. It has been noted that soiled wounds on land do badly while similar wounds in sailors who were immersed in the sea heal promptly. After serum has poured into the wound from the tissues and brought with it the deep bacteria, the wound should be washed with normal salt solution and kept at rest.

Hypertonic salt dressings may be used in the form of the *salt pack.* The wound is cleansed and all the recesses are washed out. Every crevice is then packed with gauze wrung out in 5 or 10 per cent. salt solution. The gauze is packed in pleated folds and between every third or fourth fold a 0.3 or 0.6-Gm. (5- or 10-grain) tablet of salt is placed. A large fenestrated tube is inserted to the bottom of the wound and packed about with the salted gauze. The packing should reach to the level of the skin. The skin is painted with iodin, and a copious dry dressing applied. The patient should take a large amount of fluids.

The **lactic acid treatment** of infections has proved of service in putrefactive infections and in mixed infections. Where false membranes and sloughs are present it acts well. It is especially effective in cases of colon bacillus infection. Pure cultures of the *Bacillus bulgaricus* are used in bouillon. This is applied directly to the wound after it has been washed with simple sterile boiled water.

The **glycerin treatment** of infected wounds seems to give good results in many cases. The wound may be flooded with glycerin and covered with a dressing soaked with the same. Glycerin is slightly antiseptic, non-poisonous, attracts water from the tissues, and softens crusts and necrotic tissues. Such a dressing should be changed twice daily and be kept covered with impervious material to get the best results. It acts much the same as hypertonic solution. If some antiseptic such as boric acid, is added, the antiseptic action is increased.

The application of **heliotherapy** to wounds is of much value. The exposure of wounds to the light of the sun is one of the oldest forms of wound therapy (see Heliotherapy, Vol. III). The *Finsen ray* and the *x-ray* have similar value.

The *electric light* from ordinary incandescent lamps gives positive results in promoting the healing of infected wounds. The bulbs are placed near enough to the wound to give a sense of warmth to the part. The heat and light are confined by a hood which acts as a reflector. The hood may be made of metal, enameled blue on the inner surface. The wound should be kept free from dried discharges, which may be removed by irrigating with salt solution. As often as is necessary the wound should be irrigated or cleansed, and then the electric light continued.

The antiseptic treatment of infected wounds is aimed to introduce substances which directly destroy bacteria. For most infected wounds the treatment with normal salt and hypertonic solutions is to be preferred. But in badly infected wounds with much bacterial growth, in which accessible bacteria may be washed out of the wound, antiseptic fluids may be employed. These substances may be used alone or alternating with the physiological treatment.

The old practice of introducing strong corrosive antiseptics, such as phenol and corrosive sublimate is rarely indicated. Some of the less toxic agents are to be preferred. The solutions devised by H. D. Dakin are most effective. Their active agent is chlorin.

Bottles which hold 1 liter are used. The lower opening is 7 mm. in diameter. Distribution tubes with one to four branches to run to the wound should be connected by Y-tubes. Drainage tubes should be placed in every crevice of the wound, and continuous irrigation kept going with the solution. The interior diameter of the irrigation tubes should be about 7 mm.

Dakin devised also an antiseptic, called chloramine and chlorazene, which is prepared synthetically from toluol (British Med. Jour., Jan. 29, 1916). Continuous irrigation with this substance in 1 or 2 per cent. solution is most valuable in infected wounds. In badly infected wounds 3 per cent. solution may be used. The irrigation is practised by placing rubber tubes in the depths of the wound so that all pockets are reached. These tubes have lateral perforations, and connect with a reservoir of solution. The escaping fluid should run over into a basin or tub at the bedside to which it may be conveyed by rubber sheeting.

When a soiled and infected wound comes to the surgeon, it should be cleansed of foreign matter. If dried discharges and coagulated lymph are present they may be softened by applying a copious hot, wet dressing of hypertonic salt solution for an hour. This cleans the wound. The wound may then be irrigated with the antiseptic solution, and then exposed to the sun or electric light. If the infection is virulent and the discharge profuse continuous irrigation is to be preferred.

Only the slight infections, with little or no cellulitis, are to be treated by simple daily irrigation, drainage, and a gauze dressing.

Instead of the solutions mentioned above, phenol, bichloride of mercury, boric acid, permanganate of potash, picric acid, iodin or any other of the well-known antiseptics may be used. Picric acid irrigation of infected wounds is done with 0.5 to 1 per cent. solution twice daily. As soon as new epithelium begins the strength should be reduced to 0.2 per cent.

The French surgeons have used *iodized starch*. For instilling into wounds the following solution is employed: soluble starch, 25 Gm.: boiling water, 1000 c.c.; and 1 per. cent. solution of iodo-iodurée, 50 c.c. This solution contains 0.5 Gm. of iodin to the liter. Wounds treated with this solution apparently do as well as those treated with the chlorin compounds.

The **instillation method of sterilization,** commonly called the method of Carrel and Dakin, introduces into every part of an infected wound a continuous amount of an antiseptic fluid, not for irrigation, but for asepticization. Sodium hypochlorite 0.5 per cent. solution is used. The wound is first cleansed under strict aseptic precautions, all foreign matter is removed. The skin is sterilized with iodin. Necrotic tissue is cut away. Hemostasis is secured. Counter openings are rarely needed, and when made they are not placed at the dependent parts, as the object of the treatment is to cause the retention of the antiseptic fluid.

For superficial wounds several layers of gauze are placed over the wound and a circular rubber tube (Fig. 170) perforated with many holes is placed on the gauze. As applied in France the method consisted in wrapping the ends of the tubes in Turkish toweling, and laying the tubes on the wound surface (Fig. 170*a*).

For deeper wounds a tube is passed to the depths of the wound. If the wound is a penetrating one, an unfenestrated tube should reach the bottom of the wound, and the fluid allowed to return around the outer

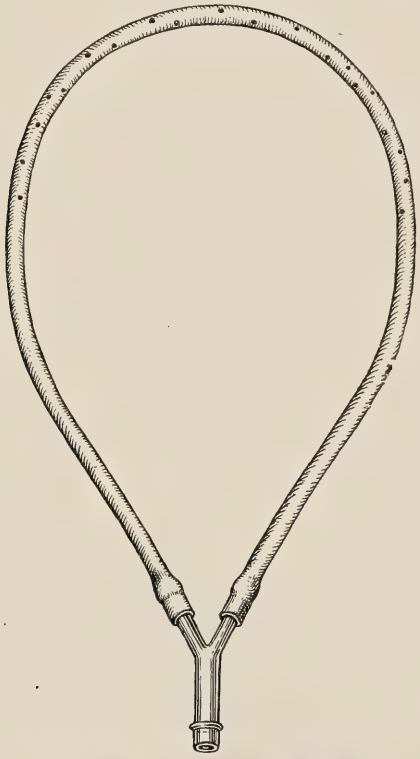


FIG. 170.—CIRCULAR RUBBER TUBE, PERFORATED WITH MANY HOLES, FOR TREATMENT OF SUPERFICIAL WOUNDS BY INSTILLATION WITH ANTISEPTIC FLUID.

sides of the tube. If the wound passes all the way through a part or has an opening at the bottom, the tube should be passed into the dependent opening to the top of the wound. The fluid then flows back along the tube. The upper opening should be plugged with a tampon of gauze to cause the retention of the fluid. Deep wounds may be dressed in such a way that the tubes pass through the dressings (Fig. 170*b*). It is always best that the tubes enter closed cavities which will retain the instilled fluid. Discharge of pus need not be provided for, because when properly carried out this treatment prevents suppurative discharge.

Wounds which are widely open should be immersed every two hours for ten or fifteen minutes in the hypochlorite solution. The skin may be protected from irritation by covering it with sterile petrolatum. In wounds which require dressing, the surrounding skin should be covered with gauze

saturated with petrolatum. In compound fractures the same principles apply (Fig. 170*c*).

In large wounds with multiple passages and excavations, a tube should pass into every crevice and cavity. Each tributary tube should have its

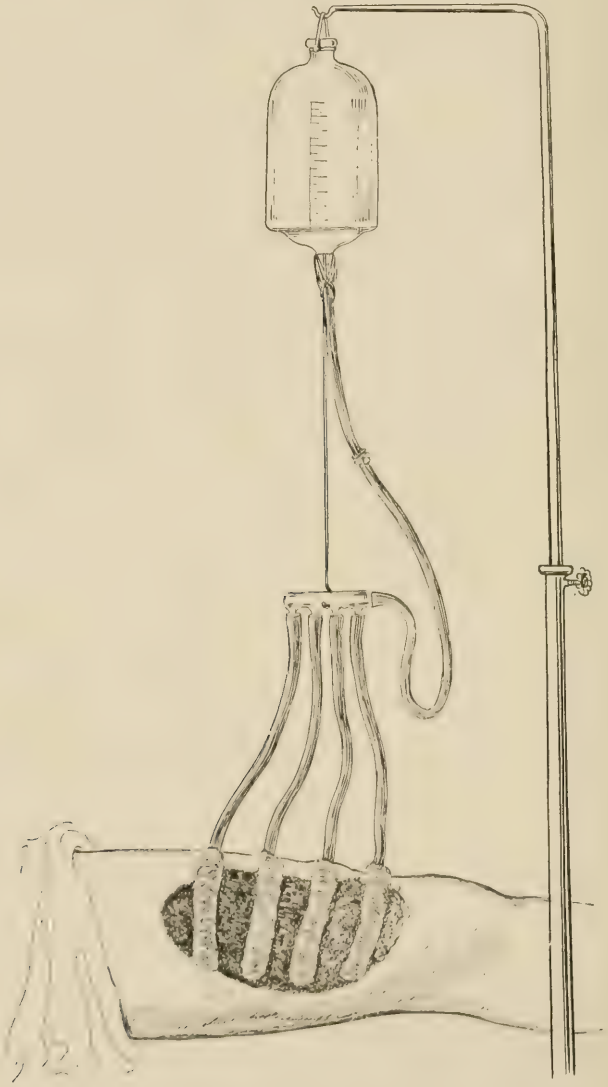


FIG. 170*a*.—HYPOCHLORITE METHOD OF WOUND TREATMENT.
Tubes with ends wrapped with Turkish toweling drip the hypochlorite solution over the wound.

extreme end closed by tying it about with a ligature. The tubes should have many perforations. All of these tubes should be connected with the common tube coming from the irrigating reservoir. For this purpose a

Y-glass tube may be used or a glass tube with multiple nipples for attachment (Fig. 171).

The tubes are left constantly in place. The fluid is allowed to flow into the wound every two hours by releasing the shutoff. The flow should be enough to bathe all of the wound but not enough to cause much overflow. The flow may be allowed to be free enough once a day to constitute an irrigation.

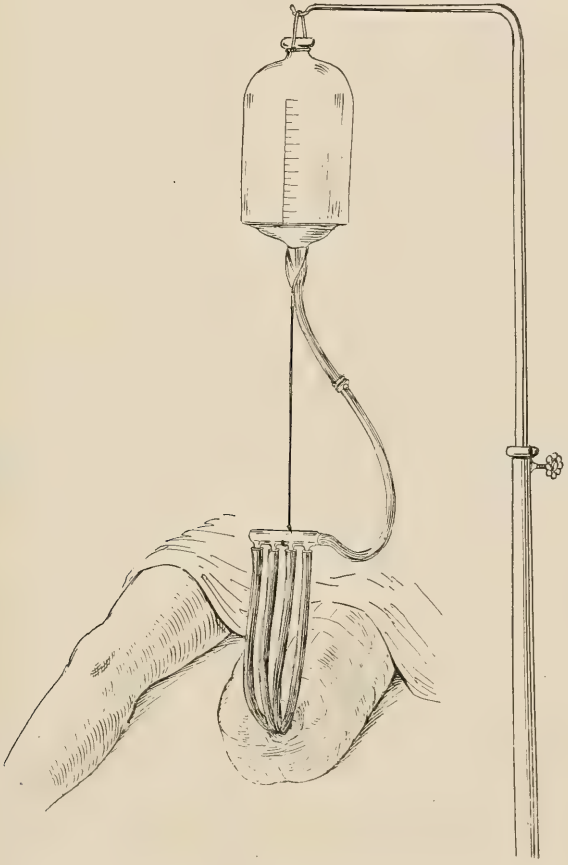


FIG. 170*b*.—INSTILLATION METHOD OF WOUND TREATMENT.
The tubes for instillation of hypochlorite solution have been passed to the depths of the amputation wound and the wound dressed.

Every second day a drop of secretion should be taken from the wound, and the number of bacteria in a given amount recorded. When bacteria have been absent for three days the wound may be regarded as sterile. It is customary in some hospitals to take a loop full of secretion from the wound once a day; when only one bacterium is found after examining twenty loopfuls, the wound may be sutured and healing expected.

By this treatment wounds of the soft parts are usually rendered approximately sterile in from five to ten days. Wounds with necrotic tissue require longer. Compound fractures require from two to five weeks. Second-

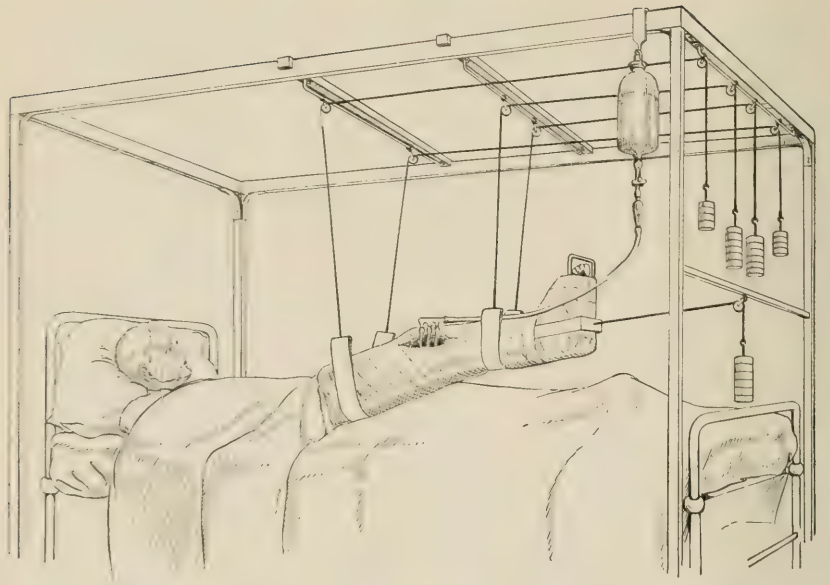


FIG. 170c.—COMPOUND FRACTURE WITH INFECTED WOUND TREATED BY INSTILLATION.

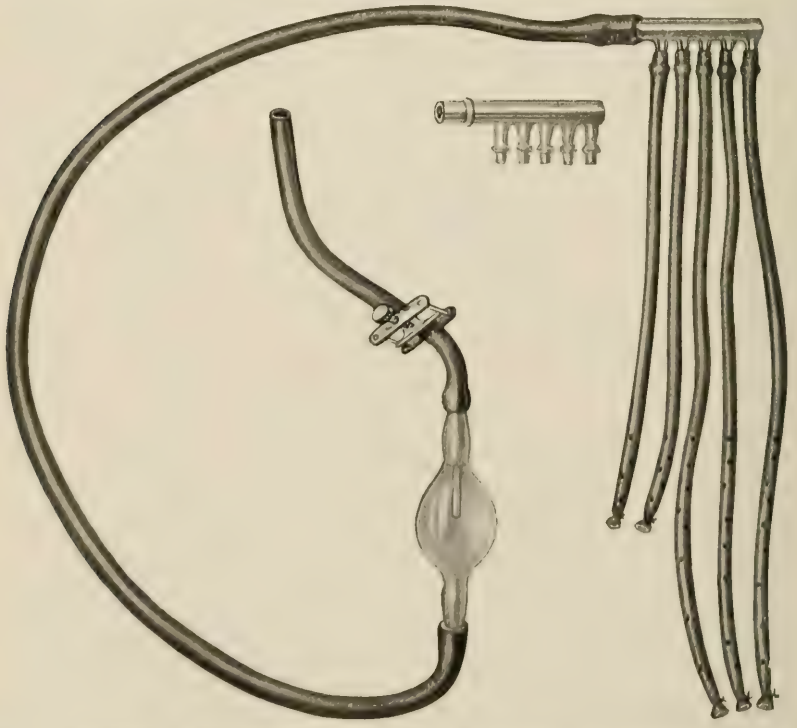


FIG. 171.—RUBBER TUBING APPARATUS FOR TREATMENT OF INFECTED WOUNDS BY INSTILLATION WITH ANTISEPTIC FLUID.

The ends of the tubes are closed. A glass dropper connection is introduced.

ary sutures may always be applied when the wound has been found free of bacteria. This bacterial control is a highly important feature of the technic.

The **hypochlorite of magnesium** is recommended as being less irritating than the chlorinated sodium solution, it does not need to be neutralized, and is cheaper. Magnesium sulphate, 190 Gm., dissolved in 2 liters of water, are mixed with 100 Gm. of chloride of lime also dissolved in 2 liters of water. After the deposit of sulphate of lime has settled the fluid is filtered. The remaining solution of hypochlorite of magnesium is less potent than the lime solution and about 8 per cent. more must be used.

The **chloraminated oil treatment** employs a more stable compound than chlorinated water. The best results are secured with chloramine.

Dakin discovered that the reaction of the living tissues to hypochlorites is the formation of certain NCl groups which belong to the chloramines. The chloramines are strongly germicidal and but scarcely irritating to animal cells. The chloramines may be prepared synthetically. One of these substances is the sodium salt of toluene-parasulphochloramine, called **chlorazene.** This substance in 2 per cent. aqueous solution is non-irritating to the skin and is about four times stronger in germicidal power than the usual solutions of hypochlorites.

The aqueous hypochlorite solutions naturally disappear rapidly from wounds into which they are instilled and require to be renewed at least every two hours. It is possible to hold the chloramines in suspension in oil so that when introduced into a wound the germicide does not so rapidly disappear but is retained in contact with the tissues and acts over a prolonged period. For this purpose **dichloramine** (toluene-parasulphondichloramine) is suspended in eucalyptol. A 10 per cent. solution of dichloramine in eucalyptol may be kept in a dark bottle for a period of one month and suffer only approximately 25 per cent. decomposition. Such a chlorinated oil in strength from 5 to 10 per cent. may be introduced into wounds in larger amounts than the watery solution and the germicidal action will continue for a period of twelve to twenty-four hours.

The technic of the application of **chloraminated oil** was described by R. G. Le Conte (Trans. Am. Surg. Assoc., 1917). It is much more simple than the so-called Carrel technic. After the wound has been prepared for dressing and all dead tissue removed, the oil is sprayed into the wound with an atomizer. If the wound is deep the oil is poured into the cavities. If there is an opening at the dependent part of the cavity it should be plugged with gauze to prevent the escape of the oil. Just before the final dressing is applied the plug is removed and the oil is allowed to escape. It is not necessary to dispense with the advantage of dependent drainage as in the Carrel technic. The oil need be applied to the wound only once in twenty-four or forty-eight hours. But a thin dressing should be applied. The saving in gauze is very great (see Chloraminated Oil, page 64).

The antiseptic properties of chlorin may be obtained from solutions made with simple **hypochlorite of sodium**. This is used the same as the other chlorin compounds. No more irritating than any of these solutions is the **hypochlorite of potassium** solution (Javelle water). This latter is an old and well known antiseptic, and may be used in strength of 15 c.c. of Javelle water to the liter. (That is equal to 0.042 Gm. of potassium hypochlorite to the hundred.) This solution may be used freely; it is, perhaps, no more irritating than Dakin's solution.

The **hot peroxide-phenol treatment** of infected wounds is commended by many British surgeons. It consists in irrigating every four hours with hot peroxide of hydrogen solution (60 c.c. to 1 liter), followed immediately

by hot phenol lotion (15 c.c. to 1 liter). The wound is then covered with a hot moist dressing.

The **ether treatment** of infected wounds is carried out by irrigating daily with about 2 litres of 2 per cent. solution of ether. It is not so much the direct antiseptic action of the ether that gives the good results but the stimulating effect on the formation of embryonic tissue. A marked stimulation in the formation of fibroblasts is promoted. The defensive powers of the tissues seem to be greatly quickened.

The **bismuth paste treatment** gives remarkable success in cases of wounds which are not associated with deep cellulitis. In the case of a ragged deep lacerated wound, the patient is given a general anesthetic; the skin is sterilized; the wound is freely opened so as to expose all of its recesses; all bleeding is checked and all foreign matter is removed; the wound is thoroughly washed with hypochlorite solution, followed by normal salt solution; or, better, it is simply mopped out with alcohol and dried. Then the wound is filled with a paste of bismuth subnitrate (1 part), iodoform (1 or 2 parts), and enough liquid paraffin to make a thick paste, having the consistency of soft butter.

The paste is spread out over the wound surface and caused to fill every crevice. Over the wound a dry gauze dressing is applied, and held in position with adhesive plaster and bandage. No change of the dressing is required for several days or a week. The dressing may remain sometimes two or three weeks without changing, the discharge may be so slight. When the dressing is changed, the discharge should be wiped from the skin with alcohol, some more of the paste applied to the skin, and a fresh covering of gauze put on. This is the method of R. Morison. The paste is called "bipp."

This treatment is especially useful in compound fractures, as the dressing may be left undisturbed for a long time, and the healing goes on smoothly. With this treatment drainage tubes and gauze drains seem unnecessary. The paste maintains a continuous antiseptic action; it provokes a moderate flow of serum; granulation tissue grows freely; septic wounds heal rapidly; union goes on uninterruptedly; and the tendency to form sequestra is but slight. Iodoform poisoning may occur if too much is used.

Compared with the treatment by frequent instillations of hypochlorite solution, this paste seems to give even better results, and is much more simple. The bactericidal action results from the free iodin liberated and from the exudation of substances inimical to bacteria which is provoked.

The **magnesium sulphate treatment** has been preferred by some English surgeons. A saturated solution is used. A solution made of 40 parts magnesium sulphate, 10 parts glycerin, and 30 parts boiling water. It is sterilized in an autoclave. In recent infected wounds the whole wound is opened up, all the surfaces are swabbed with pure phenol, the wound is packed with gauze wrung out in phenol solution (1 : 20), and covered with a copious dry dressing. At the end of twenty-four hours the gauze is removed, the wound is sprayed out with the magnesium solution, lightly packed with gauze wet with the same, and covered with a copious dressing. Later wounds, which come to the surgeon septic and suppurating, are treated at once with the magnesium solution without the phenol. Dressings are changed every twelve hours. Absorption of the salt is prevented by the layer of inflammatory cells.

The **soap** treatment of infected wounds is not a novelty. It has been in use for a long time and has warm advocates. Castile soap is dissolved in sterile water up to 20 or 40 per cent. The wound is washed with this solution. For wound tamponing, a mass of gauze is soaked in the soap solution and then rubbed with solid soap until a creamy lather is produced.

This is packed into the wound. The wound is covered with a dry dressing. The soap treatment with tampon is renewed every two or three days. Wounds so treated seem especially free from pain, they heal promptly, and require but infrequent dressing.

CHRONIC INFLAMMATIONS

Chronic inflammations are of two types: those in which bacteria are present, and those in which they are not. Both are characterized by the presence of new tissue and inflammatory products, toward the removal of which treatment is aimed. The treatment should be directed to improving the local circulation and increasing the blood supply in order to facilitate oxidation and the carrying away of these products. It is possible in this way to cause the absorption and removal of fibrous and round-cell connective tissue. Chronic and specific inflammations in which bacteria are present will be discussed in the next chapter; those which will be treated here are the conditions in which if bacteria were present they have disappeared. Such conditions are found under such diagnoses as lumbago, sciatica, neuralgia, cicatricial contractures, relics of hematoma, soft ankylosis, painful joints, chronic synovitis, cellulitis, etc.

The **nourishment** is important because the vital resistance should be brought to as high a point as possible while the ptomain absorption should be reduced to the minimum. Such toxemias as provoke "rheumatism," interfere with the recovery of chronic inflammations. The food should be nourishing but as free as can be from toxic possibilities. Active infection in other parts of the body should be cured.

Artificial hyperemia (page 229) is of value in this class of inflammations. In tuberculosis, which is discussed elsewhere, it is of great efficacy.

Massage and passive motion are among the most valuable agents for overcoming chronic inflammations where no bacteria are present. They stimulate the circulation, stretch contractured tissues and hasten the elimination of inflammatory products.

Vibration is a form of massage. It causes the circulation and absorption to be stimulated by rapidly beating the tissues, the repeated vibratory traumatisms causing a paralysis or relaxation of the constrictor muscles of the vessels and consequently an hyperemia. The mechanical pressure of the vibrating instrument adds massage to this: it therefore combines the benefits of these two means of treatment. Vibration is applied by means of instruments having balls or hand pads which are pressed against the surface and caused to vibrate rapidly by electricity or other mechanical power, beating the surface with a rapid succession of blows, which by varying the pressure are made to effect either the superficial or the deep parts. When applied over a nerve trunk it causes a relaxation of the constrictor muscles of the vessels supplied by the nerve and consequently a peripheral hyperemia.

Massage, passive motion, and vibration are means of treatment worthy of the best scientific interest. Surgery should give them more attention. They are much employed by the charlatan, in whose hands they often do much harm by being applied to acute and infective inflammations and conditions which should receive other treatment.

Hot applications are of service in producing hyperemia. The part may be immersed in water as hot as can be tolerated or a copious dressing of gauze or flannel may be applied, and kept wet with hot water. To promote the retention of heat the fabric may be covered with oiled or rubber sheeting. Heat and moisture are both of value (see Hot Applications, page 233).

Cold applications, not long continued, but made for a few seconds at a time, stimulate local circulation and elimination by causing alternate contraction and dilatation of the vessels. One of the best treatments of chronic inflammation is the combination of heat and cold. Let the part be immersed in hot water or enveloped in hot compresses for twenty or thirty minutes and then douched with cold water for half a minute or a minute and let this process be repeated two or three times daily.

Electricity has the power to stimulate the circulation and cause dilatation of the vessels. Interrupted and high-tension currents are used. The apparatus necessary makes it less advantageous than the more simple treatments, while for the very same reason it is much affected by the charlatan.

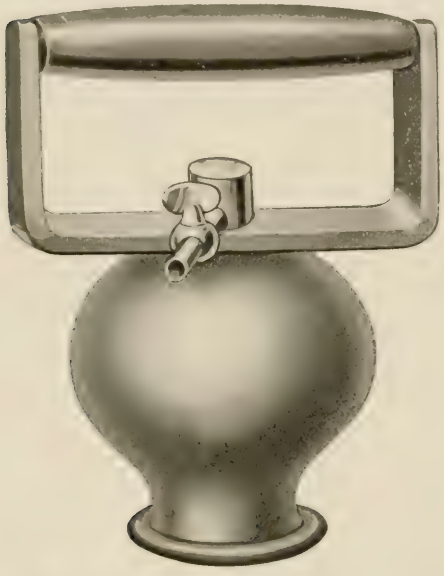


FIG. 172.—SUCTION TRACTION BELL FOR THE SIMULTANEOUS APPLICATION OF HYPEREMIA AND MASSAGE.

Rest is of value in chronic inflammations when the exudate is so great as to involve nerves, and when pain is caused by motion. It is usually necessary when swelling is present.

Pressure, made by a flannel or other elastic bandage, is often of value to hasten the absorption of serum when there is edema or serious swelling. It may be combined with elevation of the part or massage.

Suction-traction massage, a combination of hyperemic suction and massage, is applied by means of suction cups invented by Bramson (Fig. 172). The cup is applied over the inflamed area, and the air aspirated. It is then alternately pulled and pressed, thus alternating deep massage and traction in the presence of hyperemia. The skin may be oiled and the cup moved about. In lumbago, neuralgia, and old adhesions this method induced hyperemia and loosens the tissues with good results.

Skin irritation, by means of *rubefacients*, acts in the same manner as in acute inflammations by inducing hyperemia. They are applied only to healthy skin. Tincture of iodin, painted over the diseased area, four or five coats, until the skin is as dark as mahogany, is of value.

The **seton,** long since fallen into disuse, may still sometimes be applied to advantage for the purpose of keeping up a continuous congestion in the zone of a chronic inflammation. It is made by passing a heavy silk or linen thread through the tissues, and leaving it there to create a sinus. Its presence causes constant congestion.

ACUTE DIFFUSE CELLULITIS

This is a condition, the treatment of which is the same as acute inflammation, described above (page 228). The application of the hyperemic treatment or other measures should not interfere with free incision for the evacuation of pus and the introduction of drainage tubes. The surgeon

should not wait to be sure of the presence of pus but whenever pus is suspected incision should be made. This can usually be made under the anesthesia of the ethyl chloride spray, after which the pus may be reached by blunt separation of the tissues, by pushing forward in the wound with the end of round-ended scissors or an artery clamp, which can be opened to enlarge the wound when pus is encountered. Suppuration developing in the lymphatics above the disease should receive the same treatment. The exception to this treatment is in cellulitis of the extremities (see Upper Extremities, Infection of Tendon-sheaths, Vol. III).

ACUTE SUPPURATION (ABSCESS)

In general, the treatment of acute abscess consists in incision and drainage. Before the pus has centralized and the condition is still one of cir-

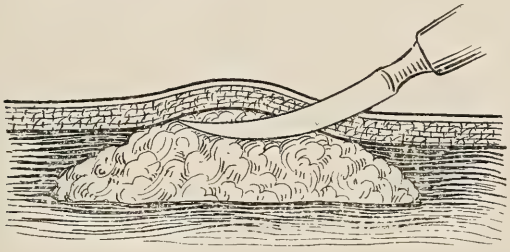


Fig. 173.—Incision of Abscess with Sharp Curved Bistoury.

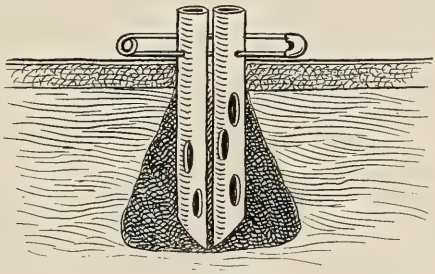


Fig. 174.—Drainage Tubes in Abscess.

cumscribed cellulitis, the comfort of the patient can be contributed to and the cure hastened by hot fomentations. My own preference is for a large compress wet with hot boracic acid solution, covered with oiled cloth and non-absorbent cotton to retain the heat and moisture. This may be changed every few hours. If an abscess forms it is opened through skin which has had the benefit of antiseptic treatment, and there is less danger of contaminating the wound with other bacteria.

The incision of an abscess should be made in the direction of the nerves and vessels and not transversely to them. Due regard should be had for the resulting scar, which should fall in the natural folds of the skin, within the hair-bearing area, in the mouth in preference to the cheek, etc. The sharper the knife, the less the scar. The hair within soiling distance should be shaved, the skin cleansed, and the operation done with aseptic precautions. The old idea that because pus is present the wound is an infected one and asepsis can be of no avail is no longer tenable. Modern surgery demands that even infected wounds shall be protected from further in-

fection. The opening need not be enormous, but large enough for the free escape of pus (Fig. 173). If the abscess holds more than 30 or 60 c.c. (1 or 2 ounces) of pus, a drainage tube should be inserted (Fig. 174). This is not a rule but a statement which must be modified by the vital resistance of the patient, the nature of the infection, the site of the abscess, and the size of the opening. In place of a drainage tube a "spreader" is often useful. This is a small spring with a retracting blade on each end. Its introduction into the mouth of the wound insures its wide open state. A most important thing is that the opening should be made in such a place as to secure the benefit of gravity in drainage. Consideration should be given to the position in which the patient is going to spend the most time. Less scar results if the abscess is opened through healthy skin. If incision is delayed until the skin has become inflamed, the resulting scar will be increased; and the scar will be greatest if the abscess is allowed to break spontaneously. Early incision, as soon as suppuration has centralized, is the thing.

If the abscess is in the region of structures which must not be wounded, the incision should be made carefully with the edge of the knife, as in a dissection, so that the structures can be identified as they are divided, and blunt dissection should be much employed. If the abscess is in some region free from important structures, such as the back, the old-fashioned method of making a quick puncture and an outward incision with a sharp-curved bistoury may be used. This operation can be done so quickly that anesthetic is not necessary. Necrotic débris which has formed in an abscess should be removed. Irrigation with salt solution or sterile water is advisable if the abscess is large, if it has pockets, if there is much necrotic material which can best be removed by irrigation, if the pus is so thick that it does not easily escape, or if it is desired to make the abscess as clear of pus as possible in order to diminish the discharge into the first dressing.

It is not best to make pressure upon an abscess to squeeze out the pus; irrigation is better. Nor should the inside of the abscess be swabbed or traumatized. Such procedures break the protective zone of young connective tissue which acts as a barrier against the spread of the infection. Pockets must often be searched for and drained. When there is extensive burrowing of pus it is better for cosmetic reasons to make several small openings rather than one large opening laying free the whole suppurating area. A small, smooth-walled abscess may often be quickly healed by aseptic incision, thorough cleansing with salt solution, tightly packing with dry bichloride gauze, covering with gauze, and tightly bandaging to make firm elastic pressure. The packing should be removed in forty-eight hours, and another compressing dressing applied as though the wound were a simple incision.

It often becomes necessary to open an abscess through a serous cavity such as the pleura or peritoneum; in which event the rest of the serous cavity should be separated by gauze packing from the part to be soiled with pus. Adhesions quickly form, and the gauze is removed after one or two days. Or protection may be secured by sewing the surfaces together instead of depending on gauze packing and adhesions. Such operations are best done in two stages, the abscess being opened after protecting adhesions have been formed.

The best dressing for an abscess is gauze wet with antiseptic solution, this being covered with non-absorbent cotton or dry gauze.

CARBUNCLE

This disease should always be regarded as serious especially in debilitated persons. The treatment should be prompt and radical. The surgeon should not wait until pus has collected, but free incision should be made at the earliest possible time. If sloughs are present they should be removed as far as possible and a wide opening for drainage should be left. From this point on healing may be hastened by applying suction cups (see page 229). The dressing should be a large compress wet with antiseptic solution. Dressings should be done at least once daily, sloughing tissue removed, and the wounds enlarged freely if the disease shows a tendency to spread. The openings should be so large that drainage should be free without consideration of the necessity for tubes or packing. In order to accomplish this, it is often well to remove an ellipse or central cone of tissue instead of making a straight incision.

Extensive carbuncle of the nape, with boardy infiltration and dusky congestion, is best treated by excision of the whole diseased area as though it were a tumor. It is striking as well as gratifying to observe how rapidly a large wound granulates and heals, especially when contrasted with the slow process secured by the method of free incision.

Cauterizing the center of boils and carbuncles with the actual *cautery* has proved successful. This treatment requires local or general anesthesia.

Deep **circular incision,** down to the muscle, carried around a carbuncle seems to stop the progress of the disease.

In **carbuncle of the upper lip,** besides the local treatment addressed to the carbuncle, if prompt healing does not occur, the facial vein should be ligated in order to prevent *infective thrombosis of the venous sinuses of the brain.* This complication is so common and so serious that the simple operation for its prevention should not be neglected.

The treatment of **boils** is the same as the treatment of abscesses (see above). One of the most effective measures is the *phenol* treatment (page 827). Before the pus has become loculated it may be aborted by injecting one or two drops of a 10 per cent. solution of phenol. A swab, on a pointed stick wet with 95 per cent. phenol solution rotated into the broken-down center of a boil is the treatment used by G. H. Fox. Boils yield also to the continuous application of hot boracic acid solution.

In sloughing infections, after freely opening the diseased tissues, and removing such of the slough as can be taken out, there is advantage in swabbing out the cavity with tincture of iodin or with pure phenol followed by alcohol. Filling the cavity with balsam-of-Peru and naphthalin also has advantages.

Every attention should be given to improving the general resistance of the patient. Vicious practices should be checked; the bowels should be kept open; and the patient should be given the advantages of fresh air, cheerful surroundings, simple and nourishing food. I vividly recall a patient whom I lost because of the lack of these aids to recovery.

Vaccination with a vaccine of the causative organism or a mixed vaccine is of service. Such vaccination is indicated in cases in which there are multiple carbuncles and recurrences after each is cured (see Vaccines, page 255).

CHRONIC ABSCESS

Chronic abscess is one not surrounded by a zone of cellulitis, or one in which the bacteria have perished. Such abscesses are commonly tubercular, but they may be due to other causes. It is important that these

abscesses should not become infected with other organisms. Usually the best treatment consists in leaving them undisturbed and directing treatment to the general health of the patient. Under good hygiene the pus disappears by absorption. If it produces pressure that is objectionable or is coming close to the skin which it threatens to perforate, local treatment is indicated. That consists in aseptic evacuation. (For the treatment of Tuberculous Abscess, see page 281.)

The **excision of abscesses** may be practised where the location and size of the abscess permits, and in cases in which a rapid cure is desired. The abscess or boil may be removed as a tumor, and the wound closed. The skin may be sterilized by iodin. In fresh abscesses the incision must be well removed from the disease. In old chronic abscess a closer incision may be made. The area of disease is removed by an elliptical incision. If the excision has been made beyond the zone of bacterial infection the wound may be sutured.

SURGICAL FEVERS AND INFECTIONS

VACCINES, SERUMS AND ANTITOXINS

Vaccines and **antitoxins** in the treatment of infections resulted directly from the discoveries of Pasteur. They apply to the general protective forces of the body, as the induction of hyperemia applies locally. If an infection is not being overcome by the body, the bodily resistance to the infection may be increased by the use of a vaccine. A culture of the infecting organisms is taken from the wound, local focus of inflammation, or from the blood, and pure cultures made. If several organisms are involved, cultures of the most strongly pathological are produced. A vigorous culture, the product of about thirty-six hours growth is made. The organisms are then killed by the lowest degree of heat possible, and injected under aseptic precautions into a muscle or connective tissue of the patient. The effect of these organisms in the body is to stimulate the production of antitoxins by the body itself.

Instead of using bacteria, the antitoxin substance, grown in some other animal, may be used. The antitoxins lower the resisting power of the bacteria and permit their destruction by leukocytes and the juices of the body. These antibodies are called opsonins, bacteriolysins and antiferments.

Protective inoculations are accomplished (1) with living organisms (as illustrated by the subcutaneous anticholera inoculations); (2) with attenuated living organisms (as in vaccination against smallpox; and (3) with dead organisms (as in inoculations against typhoid fever). This is called active immunization with infectious organisms. Passive immunization is the injection of antitoxic and antibacterial serums, containing preformed antibodies for the cure and the prevention of infections. In the former method, actual bacteria are employed; in the latter, the serum of previously immunized animals is used. The preparation of sera requires much time. Bacterins may be made in a few hours. Active and passive immunization may be combined, as in foot-and-mouth disease, anthrax and plague.

Curative inoculations for active immunization are made with dead bacteria and bacterial products with the view of hastening curative reactions.

Vaccine and **serum therapy** is the oldest therapy in the world. Animals lick the pus from their wounds and thus inoculate themselves with the antigens necessary to stimulate the formation of antitoxins. This therapy is based on the principle of exciting the formation of antibodies in the system and destruction of bacteria by them and by the leukocytes. Antibodies which are opposed to most bacteria exist constantly in the blood. Their formation is also quickly stimulated by antigens such as the bacterial toxins. These bodies are present in all infections. In a cellulitis or abscess, if enough antigen is taken into the circulation it is capable of stimulating the system to produce enough antibodies to destroy the bacteria and cure the disease. Usually this reaction produces increase of temperature, and probably requires increase of temperature for its operation.

The treatment of **suppurative infections** is usually undertaken with bacterins. **Autogenous bacterins** are those made from the specific bacteria of the disease to be treated. The best results are had in localized, subacute and chronic suppurations in which the absorption of antigens has been hindered by the barrier of fibrin and connective tissue produced by the inflammation. In very acute and generalized infections, in which there has been free absorption of bacterial toxins, and the system overwhelmed with antigenetic substances, vaccine therapy has little to offer. When the system is so overwhelmed with toxins of infection that the heart has become weak and the temperature lower, and the resistance is exhausted, vaccines are apt to do more harm than good. They may be tried if the resistance is still active, as evidenced by the strong pulse and fever, but not much benefit may be expected.

Staphylococcic vaccines give better results than streptococcic. **Stock vaccines** are made and kept on hand for immediate injection. In some cases they seem to be as effective as the autogenous vaccines. **Mixed vaccines** are also used both as stock and as autogenous preparations. J. M. Van Cott prepared a mixed vaccine of staphylococci, streptococci, and colon bacilli, which gives excellent results in cases both of mixed infection and also in certain infections with either of the organisms employed. Some surgeons have employed such a mixed vaccine as a prophylactic in cases in which infection was feared. This is a surgical expedient of doubtful value. This whole program of vaccine therapy must be regarded only as an adjunct to the well-tried methods of surgery and in no sense to take their place.

The dosage of bacterins varies with the organism, the nature of disease, and the resistance of the patient. A moderate dose of staphylococci which have been killed by heat is 50,000,000 to 200,000,000. Streptococci are given in doses of 15,000,000 to 50,000,000. Mixed vaccines may contain 50,000,000 of Streptococcus pyogenes; 100,000,000 each of Staphylococcus pyogenes aureus and Staphylococcus pyogenes albus; and 75,000,000 of Bacillus coli communis. These are large doses. It is better that the beginning dose should be small rather than large. An interval of three to six days should ordinarily intervene between doses. Vaccination should be slow and by absorption from the connective tissues and not sudden by injection of the vaccine into the blood-stream.

As a rule it may be said that the results are best from autogenous vaccines. For rapid absorption the killed bacteria are suspended in salt solution. Slower and continuous action is better, and is secured by suspension in lanolin and olive oil (lipovaccine). In acute gonorrhea, vaccine seems to be of little value, but in gonorrheal arthritis it is effective. It may be said that the best surgical results are secured in infections of bladder and kidneys, gonorrheal infections of joints, peritonitis, post-operative pneumonia, furunculosis and nasal sinus infections. In gonorrheal vulvovaginitis in children, doses of 5,000,000 dead gonococci in a stock vaccine, even without local treatment, cure the infection in from ten to thirty days, after three to ten inoculations. In gonorrheal arthritis and tenosynovitis, 50,000,000 gonococci in a stock vaccine are an average dose, and two to four injections over a period of from three to four weeks either cure or improve the condition. Acne vulgaris and furunculosis, treated with autogenous cultures of *Micrococcus aureus* and *albus*, are cured in from ten days to five weeks. Carbuncle is cured with autogenous *Micrococcus aureus* in from five days to three weeks.

Vaccine and serum therapy in **septicemia** seems to benefit most cases which have not been overwhelmed by the severity of the initial infection.

During the early stages of the infection antistreptococcic serum is of much value. If it is given in sufficient amount it may check the systemic invasion and convert the disease into a local infection. It is best to give the serum at once and follow it by autogenous vaccine as soon as the latter can be made from blood cultures. If the blood cultures are sterile, a vaccine should be made from the wound or local infection.

Puerperal septicemia (following labor and abortion) is prevented by maintaining the pregnant woman in the best possible state of health and sparing her from the obstetric introduction of bacteria into her parturient canal (see Diseases of Women, Vol. III). Streptococcic bacteremia usually exists. A high leukocyte count (25,000) usually indicates some complication which requires special treatment. Such complications are pelvic abscess, peritonitis, phlebitis, empyema, pneumonia, endocarditis, arthritis, meningitis or other focus of infection.

The uterus should be expected to empty itself spontaneously. The gentlest manipulation should be practised so as not to produce new wounds or abrasions. Instruments should not enter the uterus. Gauze packing should be used only to control bleeding. The patient should be in the open air.

Antistreptococcic serum, if used, should be given at once. The autogenous vaccine follows as soon as possible. The results of this treatment are not striking. The serum and vaccine seem to do no harm. The indications are that they do some good.

In **septicemia following wounds** and **abscesses** the results of vaccine treatment have been so good as to warrant its use as a routine measure. The same may be said of cases following **joint infections** and **osteomyelitis.** In the septicemia of **endocarditis, pericarditis, empyema** and **meningitis,** the results of serum and vaccine treatment have not been encouraging.

At least a dosage of 40 to 100 c.c. of serum must be given daily.

In **tuberculosis** bacterial therapy has decided value. The *dose* in febrile cases should be one-tenth the dose used in afebrile cases. The preparations used are tuberculin, the bacillus emulsion (B. E.), and the dead whole bacilli. Tuberculin is used in doses of 0.00000001 mg. to 0.005 mg. The bacillus emulsion (B. E.) is given in beginning doses of 0.0001 mg., or less, and increased 25 per cent. weekly up to 0.001 mg. The vaccine of dead bacilli is given in doses of from 100,000,000 to 400,000,000 bacilli. Osler and McCrae give the beginning dose of B. E. at 0.000001 Gm. for afebrile cases, and 0.0000001 Gm. for febrile cases. This is also the dose for T. R. For T. O. the beginning dose is given as 0.0000005 or 0.0000001 Gm., and in febrile cases 0.00000001 Gm. Autogenous preparations are to be preferred, but stock preparations are commonly used. Inoculations are given about once a week. Where mixed infections are present autogenous vaccines should be made from the infective focus. If there are several dominant organisms they should all be used in a mixed vaccine. These should be used until the temperature has been reduced to (100°F.) and then the tuberculin treatment should be inaugurated. Acute tuberculosis is not amenable to bacterin treatment.

The *tuberculin* of Koch is made of cultures of tubercle bacilli, of six to eight weeks' growth, in 4 to 5 per cent. glycerin-peptone broth. The organisms are killed by steam, the broth evaporated to one-tenth its original volume, and the residue filtered. This fluid contains 40 to 50 per cent. glycerin. Dilutions are made with 0.5 per cent. phenol. This was the original method of Koch. Later he used the organisms themselves in making the *new tuberculin* or *Tuberculin Rückstand.* Dried and powdered cultures

of virulent tubercle bacilli are extracted and preserved with 20 per cent. glycerin. This is called *tuberculin R* (T. R.). It contains 2 mg. of tubercle solids to 1 c.c. Instead of bringing the dried sediment into suspension with glycerin and water it may be mixed with a suitable base and made into hypodermic tablets. The injection of minute doses of tuberculin R. stimulates the production of antituberculous substances in the body.

Sensitized bacillary emulsion of tubercle bacilli (S. B. E.) is prepared by growing the bacilli in an antituberculous serum, and then washing the bacilli to remove the excess of serum. The bacilli are then put into an emulsion containing the equivalent of 5 mg. of dried bacilli to 1 c.c. It is used in initial doses of 0.0000001 c.c. to 0.00000001 c.c. (in children 0.000000001 c.c.) or even less, and gradually increased. It is given at weekly intervals; but this may be increased or diminished. The dose may be increased up to 0.0001 c.c. as tolerance is established. Sensitized emulsion seems to have about the same effect in surgical tuberculosis as the ordinary bacillary emulsion.

The bacillus emulsion (B. E.) is prepared from dried bacilli, ground for several weeks in a ball mill; and the disintegrated bacilli are mixed with glycerin. The product is standardized so that each cubic centimeter represents a definite amount of tubercle solids. Koch mixed 5 mg. to the cubic centimeter. Instead of mixing with glycerin the dried ground product may be mixed with a suitable base and made into hypodermic tablets.

Another process used by Koch consisted in drying and then grinding the dead bacilli. The ground-up bacilli are mixed with water and the bacilli separated with the centrifuge. The supernatant fluid is called "Tuberculin Oberst" (*Tuberculin O.*).

Wright believes that tuberculin is of distinct value. His plan is to give not more than 0.001 mg. of Koch's tuberculin R. The dose should never be more than 0.0016 mg. Inoculations are made every ten days or two weeks. The patient should be kept in bed a few days before and a few days after the injection. The dose should be so small as not to produce local or general reaction. Reaction should be regarded as an evidence of intolerance. Especially good results are reported in the treatment of tuberculous glands of the neck and ulcers.

The treatment of suppuration by **pus inoculations** has been used with success. It is amenable to the general rules of vaccine therapy given above. Pus taken from the wound is sterilized by heat or by treating it for twenty-four hours with 1 per cent. phenol and camphor solution. The phenol and camphor do not injure the potency of the antigens in the pus. Such a vaccine contains not only the identical organisms which are to be combated but the active ferments and antibodies. The beginning dose of this sterilized pus is 0.12 c.c. (2 minims). Injections may be made daily. The dose may be increased 0.06 c.c. (1 minim) every day up to 1 c.c. (15 minims). When this maximum dose is reached, if it is necessary to continue the treatment, 0.6 c.c. (10 minims) may be given every second or third day. Each injection causes a slight rise of temperature and local induration.

The **technic** of vaccine injections requires absolute asepsis. A sterilizable syringe is used. The injections are made with a sharp needle into the subcutaneous connective tissue or into the muscles.

This whole subject of vaccine and serum therapy in surgical diseases is still in the experimental stage. It should be conducted by an expert laboratory worker. The surgeon can not be expected to master the subject.

Sodium succinate in infections causes an increase in the number of leukocytes. The subcutaneous injection of sodium succinate, in doses of 0.1

or 0.2 c.c. of a 1 per cent. solution, causes the number of leukocytes to increase 15 to 30 per cent. or more. This increase is observed in both normal and pathological cases. In some exceptional instances the increase does not take place. The drug is administered subcutaneously. The blood change will be observed to have taken place inside of three to six hours. The leukocytosis lasts for several days and then can be brought about again by a second injection. Whether this treatment is of value in infections remains to be seen.

ASEPTIC SURGICAL FEVERS

The important matter in the aseptic surgical fevers is that the surgeon should be sure of his diagnosis. Elevation of temperature following operations and wounds, not due to microbic infection, are called aseptic. These aseptic fevers are due to several causes. Commonly the fever is caused by the absorption into the blood of the fibrin ferment from clots in the wound and in the termini of closed vessels. This requires no treatment; but it may be the sign of hidden hemorrhage which should receive attention. Other ferments, albumoses and nucleins, are also capable of causing fever; also wounds affecting the basilar ganglia may give rise to fever by interfering with the heat centers. These fevers require no special treatment. The rise of temperature which is nervous or hysterical is worthy of consideration, and its cause should be recognized and if possible eliminated. The absorption of iodoform in poisonous amounts causes fever, which should be met by removing the iodoform. The gauze may be withdrawn and the wound irrigated. When the fever is due to thrombosis or embolism it should receive the treatment which those conditions demand.

PTOMAIN POISONING AND INTESTINAL TOXEMIA

While the absorption from the intestine of the products of decomposition and fermentation is a medical condition, still it often gives rise to fever and toxic symptoms in connection with surgical conditions and calls for relief. Its prophylaxis is accomplished by attention to the rules of diet already laid down. The treatment consists in the emptying of the intestine by laxatives and enemas, the administration for a few days of no food, or of food which leaves no residuum, and if necessary the flushing of the colon with water.

SEPTICEMIA

The septicemias which will here be discussed are those which gain entrance to the body through wounds, large or small; excepting the toxemias, such as tetanus, anthrax, tuberculosis, syphilis, etc., which are discussed separately. The sepsis of this class which the surgeon is most commonly called upon to treat is true bacteremia, and is due to one or more of the following bacteria: *Streptococcus pyogenes, Staphylococcus pyogenes aureus, Staphylococcus pyogenes albus, Micrococcus tetraganus, Bacillus pyocyaneus, Bacillus coli communis, Meningococcus, B. proteus vulgaris,* and *B. aerog. capsulatus.* The mortality ranges between 50 and 75 per cent.

The prophylaxis of septicemia resides in the principles of aseptic surgery —the protection of wounds from infection. The good health of the individual is also of much importance. The person who is poorly nourished, septic from intestinal toxemia, alcoholic, syphilitic or tuberculous, suffers the greatest dangers from septicemia. Care should be exercised in handling septic wounds and decomposing material lest infection take place through an abrasion of the skin or lest dangerous bacteria be conveyed to a wound. In

the hospital, septic wounds and patients should be kept apart from clean wounds and from patients about to undergo operation. The use of rubber gloves in the dressing of septic wounds has been one of the great advances in hospital surgery.

An important step in the treatment of septicemia is that the surgeon shall know what bacteria are causing the trouble. This is determined by clinical, cultural and microscopic study. The local treatment demands the relief of septic conditions in the wound. Free incisions and drainage to secure perfect vent for retained secretions and the securing of a healthy granulating lining to open wounds and cavities are essential. Streptococcic infections require free and more extensive incisions than staphylococcic infections as they do not tend to throw out the protective inflammatory barriers of the latter. The principles laid down in the previous chapter for the treatment of surgical infections should be applied. The most effective local treatment is that which aims to increase the local hyperemia after the best possible drainage and evacuation of toxins has been secured.

When the surgeon has failed to check the progress of a septicemia, developing in a wound of the extremities, the disease having spread from the wound into the adjacent tissues, and local and constitutional treatment having been of no avail, the life of the patient being threatened, as evidenced by a failure of resistance and the development of signs of irritation or failure of the kidneys and other emunctory glands, amputation of the limb at the joint above the uppermost limit of the local disease is indicated if the condition of the patient warrants it.

The general treatment of septicemia demands that the nourishment and resistance of the patient be brought to the best possible state. Fresh air and sunshine are most important adjuncts to whatever other treatment is used. The patient should be put out of doors and fed according to the principles already laid down—the most nourishing diet possible consistent with the minimum of residue, without overtaxing the stomach and with a maximum of animal fats such as found in cream, butter and eggs. Alcohol I believe to be more harmful than beneficial. Strychnia, antipyretics, iron, hypophosphites, arsenic, cod-liver oil—all of which have been used—have done more harm then good in septicemia.

The employment of **vaccines** and **antitoxins** in septicemia seems destined to be worked out as is one of the most important advances in surgery. This treatment is employed when local and other constitutional measures seem inadequate. It should not be deferred until the vitality of the patient has ebbed beyond recovery; but it should be gotten under way even before it seems necessary. (For the technic and general principles, see page 255.)

The treatment of staphylococcus septicemia by the *transfusion of immune blood* (R. S. Hooker, Arch. Int. Med., 1914; Annals of Surg., Nov., 1917) is highly effective. The donor is immunized by vaccination with progressively increasing doses of fresh vaccine made from the infecting organism.

PYEMIA

Septicemia with metastatic abscesses is a still more grave condition than septicemia alone. When due to septic thrombosis or embolism it is one of the gravest of surgical conditions. Gonorrheal and typhoid metastatic infections are less serious. The thrombo-embolic pyemia, being a result of infection entering the blood, should be guarded against by all of the precautions of asepsis. So far as wounds go, the surgeon can prevent the disease; but when the gate of entrance is the suppurating middle ear, diseased tonsils,

decayed teeth, intestinal ulcers, or rectal fissures, often his first intimation of its possibility is the appearance of the disease itself. The presence of an infective thrombosis must always be looked upon as a grave condition, especially when occurring in weak patients, and worthy of radical treatment (see Thrombosis and Embolism). The general prophylaxis of pyemia is similar to that of septicemia. The treatment is the same, excepting that in pyemia the septic foci declare themselves and require to be exposed, removed or evacuated. This should be done so long as the patient's general condition will stand it, but it is futile to continue opening abscesses in a moribund patient. The constitutional treatment by vaccines, made from the specific infecting organism, is most important. It should be resorted to as soon as the disease declares itself. The treatment of these cases as "rheumatism" is one of the sins of the past.

SURGICAL SCARLATINA

Scarlatina occurring in a surgical case as a complication, should be met by isolation and the general treatment of that disease; but the more common scarlatiniform rash is an erythema, due to septicemia, and requires first to be correctly diagnosed and then to receive the treatment which the septicemia demands.

SEPTICEMIA OF UNKNOWN ORIGIN

Toxemias occur in which the symptoms are clearly those of an infective process, but neither the nature of the infection nor the gate of entrance can be determined. These are, properly, internal diseases, but they are so similar to surgical infections and so prone to culminate in surgical conditions that the surgeon often is called upon to deal with them. Blood cultures, serum and bacterin tests and thorough examination having failed to reveal the nature of the infection, the general strength of the patient should be maintained by the best possible hygiene. In such cases as this injections of *sea water* (*plasma marina*) have given good results. Beginning with 30 c.c. (1 ounce), injected into the subcutaneous tissues of the back, the dose is increased to 60 c.c. (2 ounces) injected twice a week. This may be continued for weeks or months. The sea water may be obtained from the deep sea far from land and kept in a refrigerator, or near-by sea water may be sterilized. This latter is rarely necessary as the natural condition of sea water is to be sterile. If the injections cause pain the sea water may be diluted with three times its bulk of plain sterile water.

Intravenous injection of antiseptics in severe general infections seems to have some value in certain cases. The value of salvarsan, neosalvarsan and mercury is well established. Recently hypochlorous acid in the form of eusol has been employed in septic infections. It has been used with apparent success in cases of infections with gangrene. The injection is made with a simple two-way syringe with a stop-cock shunt. The needle is inserted by puncturing the vein at the elbow. Some saline should first be injected. Then the eusol is drawn into the syringe and 50 or 100 c.c. injected. If the patient bears it well the later dosage may be 150 c.c. Some saline should follow the injection.

PYOCYANEUS INFECTION

Infection with *Bacillus pyocyaneus* should be treated by the general principles already given for the treatment of wound infections. It clears up very promptly under the use of 2 per cent. solution of liquor of acetate of

aluminum. Wetting the dressings with this solution and packing the wound with gauze wet with the same promptly destroys the organisms of green pus.

The phenol-camphor treatment is also effective. Gauze wet with a solution of 30 parts phenol, 60 parts triturated camphor and 10 parts alcohol is used for packing the wound.

STREPTOCOCCUS INFECTION

Infection with **Streptococcus pyogenes,** as found in cellulitis, abscesses, lymphangitis, septicemia, osteomyelitis, puerperal infections and peritonitis, is a most serious infection, and is much more resistant to treatment than the staphylococcic infections. One reason for this is that it does not excite the herding of leukocytes and the deposits of lymph and fibrin which tend to circumscribe and check the progress of staphylococci. The local treatment of streptococcic infections is the same as that described for wound infections, cellulitis, abscess and the other conditions in which streptococci play a rôle.

It can not be gainsaid that streptococcic serum does good in some cases. If a potent serum is obtainable it should be used. Large doses are necessary to give results. From 45 to 90 c.c. (1½ to 3 ounces) or more should be given daily. An autogenous vaccine may also be of service.

DIPHTHERIA

Infection of wounds with diphtheria bacillus is not so uncommon but that the surgeon should have it in mind when treating wounds with membranous deposits which refuse to heal. The treatment is the same as for diphtheria—injection of diphtheria antitoxin and the local application of antiseptics.

ERYSIPELAS

Erysipelas, although an infection of the skin with streptococci, is not so serious a disease as other streptococcic infections, and naturally tends to recovery excepting in patients already weakened by infective diseases or alcoholism. The mortality is from 8 to 12 per cent., and is almost wholly among the debilitated and alcoholic. Because most cases recover is the reason why such a multitude of treatments have been reported as successful. Erysipelas patients require isolation no more than other streptococcic or infective cases. The ordinary surgical methods will protect the other patients. Wounds infected with streptococci or any other pathogenic organism should be dressed with gloved hands if the dresser is to have to do with other wounds; instruments should be sterilized after use; and dressings should be burned. In erysipelas the organisms do not come through the skin, and if the disease is kept covered with dressings, the patient can not scratch and break the skin and liberate the streptococci. In erysipelas which is connected with an open wound, the wound should receive the treatment already laid down. Closed wounds need not be disturbed unless there are evidences of infection in the depths of a wound, in which event it should be opened and freely drained. If there is no pus a copious gauze drain is best. Pus calls for drainage-tube and gauze.

It is best that the inflamed skin should be kept covered with gauze wet with antiseptic solution. On the face, boracic acid, borosalicylic solution or liquor aluminii acetatis may be used. The benefit of the moisture may be further secured by covering the dressing with waterproof cloth.

Phlegmonous erysipelas should have added to the above measures free incision of abscesses and the removal of necrotic tissue. Abscesses forming in such cases should be recognized as early as possible as the destruction of

tissue going on in the region of the confined pus is apt to be extensive. Sloughs form and burrowing takes place, which can only be prevented by free incision. In phlegmonous erysipelas the incisions should be longer than in the opening of other abscesses. The full length of the cavity should be widely laid open. The earlier that collections of pus are liberated the better. Painful and intense swelling, even without pus, is often treated to advantage by incision.

Many methods of treating the unbroken skin in cases of uncomplicated erysipelas are in use. Hot compresses, wet with physiologic salt solution, and changed every four hours, is a simple and effective treatment. It does not abort the disease, but it protects the region, reduces pain, and assists the local reactions against the infection. Dry heat, applied by means of a hot-water bag wrapped in a dry cloth, an electric heating pad, a blast of superheated air or by means of a hot smoothing-iron, used for fifteen minutes three or four times a day, has much the same effect as hot stupes.

Saturated solution of magnesium sulphate, used to keep gauze constantly wet, is reported to give comfort. An ointment of 15 per cent. of chlorinated lime is useful.

Nothing, that I have found, gives the patient so much comfort as cold applications. A bowl of boric acid solution, containing a piece of ice, into which compresses may be dipped and laid on the inflamed skin, is a most comforting adjunct to treatment. This is especially useful for the face. Infections of the body are best treated with compresses wet with mild antiseptic solutions.

Bland non-irritating powders such as salicylated starch are useful. S. H. Milliken (Annals of Surg., Aug., 1917) thickly dusted the area with powered stearate or zinc, and reported results which were superior to those secured by other treatments.

A large variety of local treatments have been employed. All have had their advocates and their periods of reported success.

Painting the infected skin with pure phenol until it turned white and at once applying alcohol was once much used. But an inch or two at a time should thus be phenolized before the alcohol is put on. Sloughing is sometimes caused by this treatment.

Colloidal silver, tincture of iodin, iodoform and collodion paint, phenol ointment and permanganate of potash solution have all been employed as local applications. It is doubtful if any of these measures check the disease in the slightest degree.

Ultra violet radiation is reported as useful. The light from the quartz lamp is given for ten minutes daily at first, and increased daily by two to five minutes. The lamp should be 70 to 100 cm. distance.

The streptococcus of erysipelas causes but little herding of leukocytes or deposit of fibrin. It erects no barriers to stop its progress as do staphylococcic infections. Therefore, circumscribing the disease or heading it off with an incision just through the skin, or with multiple scarifications, is supposed to be effective because these operations set up a hyperemia and inflammatory barrier beyond which the disease is not apt to pass. Local irritation of the circumference with iodin is thought to accomplish the same effect. If in a position where it can be applied, the constriction of an elastic band, pressing the skin, may act as a barrier against the advance of the disease and at the same time give the diseased skin the benefit of increased hyperemia. **Erysipelas neonatorum** should be prevented by aseptic treatment of the umbilical cord.

The constitutional treatment is the same as for inflammations (page 228)

and septicemia (page 259). The best possible hygiene is imperative. Antistreptococcic serum is used in initial doses of 30 c.c (1 ounce), followed by doses of 15 c.c (4 drams) every four or six hours. Vaccination with stock, polyvalent and autogenous bacterins gives about the same results as other treatments. After an attack of erysipelas the skin should be kept clean and protected from abrasions as there is a peculiar susceptibility to recurrence and to infections, resulting in abscesses.

Erysipelas is a self-limiting disease. Its course is seven to ten days. Most probably neither vaccines, phylacogens, sera, antiseptics, or other treatments or applications shorten its course. The strength of the patient should be conserved in every way. Knowing this the surgeon will not waste attention upon useless treatments. The skin should be kept free from other bacteria.

The **curative effect of erysipelas** upon certain diseases has been noted. These are local tuberculosis, lupus, old ulcers and sinuses, eczema, granulating wounds and sarcoma.

Erysipeloid is to be treated as an infective erythema. Mild antiseptic dressings are best.

CELLULITIS

Cellulitis is present in the beginning stage of most inflammations and in acute abscess. The general rules for treatment will be found under those heads. It is best met by the use of artificial hyperemia applied by the method of Bier and by moist fomentations of warm antiseptic solution or by immersion in the solution. When a collection of pus is suspected or when the swelling and tension become great, aseptic incision should be made. Drainage with rubber tubing is always preferable to gauze; and moist dressings are preferable to dry dressings unless there is maceration and irritation of the skin. Prompt liberation of pus and free drainage are the means to be depended upon to minimize destruction of muscles and adhesion of tendons. The relief of tension is also necessary in order to obviate ischemic paralysis. Cellulitis leaves an infiltration with inflammatory tissue, giving rise to induration, adhesions and atrophy of muscles. When the acute process has entirely subsided the treatment becomes that of chronic inflammation (page 249), for the relief of which massage is one of the most effective measures (see Cellulitis of Hand and Arm, Infections of Tendon-sheaths, Vol. III).

TETANUS

The treatment of tetanus is difficult because the surgeon does not know that the patient has tetanus until the disease has reached the spinal cord and manifested itself in producing muscular spasms. These first spasms of muscles should not be thought of as the initial symptoms, but rather as the later manifestations of a disease well advanced toward a lethal termination. The treatment of tetanus should first be aimed at prevention (see the section on Wounds Soiled with Earth, page 221, for a discussion of prophylaxis). The efficacy of tetanus antitoxin and its harmlessness have been well proved. It is an absolute preventive of the disease if injected before the tetanus germs have multiplied in the wound. Every wound in which there is a suspicion of tetanus infection, every blank cartridge wound in which the wad is lodged in the tissues, every wound soiled with earth from ground containing horse manure or dirt of the streets, and punctured wounds of the sole of the foot and palm of the hand, should have an immunizing dose of antitoxin. The wound should also be laid open and treated according to the methods already described.

The following rules may be laid down for the preventive treatment in wounds which may give rise to tetanus:—(1) A subcutaneous injection of 1500 units of antitetanic serum should be given at once, and repeated upon the appearance of any sign of tetanus. (2) The wound should be incised freely and opened to the air. (3) Every bit of foreign matter should be removed from the wound. (4) The wound should be dried and swabbed with liquid phenol, followed by alcohol; or it should be swabbed with tincture of iodin. (5) A small dressing of gauze, wet with antiseptic solution, should be used to cover the wound. (6) The wound should be kept open, dressed daily, and allowed to heal by granulation.

The tetanus bacillus is an anaërobe and perishes when exposed to oxygen. A deep wound without much foreign material need not be feared because of the oxygen of the blood. An open or superficial wound, unless foreign material or slough is present is exposed to the air. The wounds which require attention are those in which the tetanus germs are protected both from the blood and the air by an envelope of dirt, foreign body or necrotic tissue, and are sealed in the tissues. Prevention is the important thing.

In cases of **frost-bite,** especially occurring in feet which are soiled with earth, in a tetanus-breeding region, antitetanic serum should be injected, as these cases are most prone to develop the disease.

The use of **dried antitetanic serum** is of much value in cases in which a syringe can not be used. For travelers in remote places it is useful. As a prophylactic the dried serum is placed in the wound and a dressing applied. Antiseptics should not be used in connection with it.

When the muscular spasms and other signs of the disease have appeared four conditions must be given attention: efforts to neutralize the poison should be made; the primary focus of infection should be removed; the spasms should be controlled as much as possible; and elimination of the toxin should be encouraged. The vigor of the treatment must depend somewhat upon the prognosis, which is very bad in cases having an incubation period of ten days or less, and which improves the longer time over ten days has elapsed between the time of infection and the time of the appearance of the first muscular spasms. Exaggerated knee-jerk or a diffuse backache develops in some cases as a premonitory sign before the muscular spasm appears, and should prompt the surgeon to begin treatment at once in a patient who is a candidate for tetanus.

To neutralize the toxin must always be the therapeutic aim. At present our best measures but feebly accomplish this object. While the tetanus antitoxin is an infallible preventive of the disease by making the tissues of the body uninhabitable for the tetanus bacillus, still when the toxins of the bacillus have once been developed in the body and reached the spinal cord through the motor nerves in sufficient amount to produce muscular spasms, the antitoxin has little power to neutralize it. In the case with muscular symptoms the antitoxin should be used as soon as possible with the object of preventing the continuation of tetanus propagation as the toxin will not affect nerve tissue occupied by antitoxin. But at this stage of the disease it is too late for it to be of much service. It is one of the tragedies of surgery that in the fatal cases of this terrible disease the surgeon stands at the bedside of the dying patient with the remedy, which if used a few days earlier would have prevented the disease, but which now is powerless to save!

The antitoxin should be injected with the view of reaching the motor nerves and the cord and also the primary focus and the nerves in its vicinity. To accomplish this most effectively injections should be made into the trunks of the nerves if the infection is in an extremity. The great sciatic,

the crural and obturator are injected if the wound is in the lower extremity; and the brachial plexus is injected if the wound is in the upper extremity.

Immediately upon the appearance of symptoms, 10 c.c. (⅓ ounce) of antitetanic serum should be injected under anesthesia in the vicinity of the wound and in any exposed muscle tissue. The important nerves should next be exposed and 1 c.c. (15 minims) injected into them. Then, after withdrawing about 10 c.c. of subarachnoid fluid, an equal amount of antitoxin may be injected into the subarachnoid space in the spine. This may be followed with the use of magnesium sulphate, chloral and the cleansing of the wound. Chloroform anesthesia is desirable for the spinal injection and for other operations which may be painful.

F. R. Torres, of Buenos Aires (Semana Medica, Sept. 26, 1912), injected at once 120 c.c. of antitoxin in a vein. This he calls the saturation dose. This is given twice in the first twenty-four hours. On the second day an intravenous injection of 100 c.c. is given, and repeated every day so long as symptoms last. His rule is to give saturation doses every six hours till improvement is apparent.

It should be remembered that repeated doses of serum are apt to produce anaphylaxis, the urticaria and other symptoms of which should be watched for. This must be treated by the injection of much water, by intravenous infusions and by warm baths. Experience is teaching that intramuscular injections, made between the wound and the spinal cord in the path of the nerves, are effective. The spinal and intravenous injections apparently possess only theoretical advantages over this.

In severe cases in which the symptoms are generalized, an intravenous injection of 30,000 units, given with the patient under deep chloroform anesthesia, is called for. The important element in serum treatment is the administration of large doses at the earliest possible time. This is easiest done by the intravenous route.

As a result of treatment of many cases during the war, American surgeons agreed upon the following methods:

The wound is cauterized as soon as possible with phenol and alcohol or the actual cautery; 10,000 or 15,000 concentrated units of antitoxin are injected around the wound; and 20,000 to 70,000 units are injected into a vein. After 30 to 50 c.c. of spinal fluid are allowed to escape, 20,000 units of concentrated antitoxin are injected into the subarachnoid space of the lumbar region. The injections should be given all within a period of twenty-four hours. As much as 80,000 units have been given in this intensive dosing. Because of the danger of *anaphylaxis* no more antitoxin is given. To give many doses over a considerable period invites anaphylaxis. In cases in which patients have previously received antitoxin for former wounds measures must be taken to prevent anaphylaxis. This may be done by the primary injection of 1 c.c. of antitoxin slowly into a vein, followed ten minutes later by the injection of 10 c.c. under the skin. This seems to be followed by no serious disturbance.

J. Rogers, of New York, injected 0.5 to 1 c.c. into the nerves; 10 to 20 c.c. subcutaneously near the wound; and 10 to 20 c.c. intravenously. He also injected 10 to 20 c.c. into the substance of the cauda equina. If the patient's life was in imminent danger he injected 1 to 2 c.c. into the substance of the cord between the sixth and seventh cervical vertebræ. This is the most radical treatment devised. It is perhaps unnecessarily complicated.

C. A. Porter, of Boston, advocated injecting antitoxin at once into the substance of the upper part of the spinal cord. Injection of the vital

nerves, such as the spinal accessory, has also been advocated. The most commonly employed treatment consists simply in the injection of 10 to 20 c.c. every four hours deeply into the muscular tissue. Many surgeons now make a lumbar puncture into the subarachnoid space, allow a good amount of spinal fluid to escape and then inject 20 c.c. of antitoxin. Half of this amount is used for a child. The injection is repeated every two or three days. Subcutaneous injections are also made. An anesthetic may be combined with the injection.

The primary focus of infection should be removed. If the wound is a punctured wound, the whole wound tract should be excised by an elliptical incision under local or general anesthesia and left open. Larger wounds should be treated in the same way or freely laid open to the air and cleansed with peroxide of hydrogen and lightly packed. Amputation is advisable in extensive lacerated wounds and in bad compound fractures.

Control of the spasms is necessary to save the patient from pain, to conserve his strength and give him rest. This must be done by drugs. *Chloral* seems to serve well in 2-Gm. (30-grain) doses. As much as 12 Gm. (3 drams) may be given in twenty-four hours to a strong man. It may be given by mouth or rectum. *Chloretone* is even better than chloral; convulsions are controlled by 0.3 Gm. (5 grains) injected with water into the rectum every hour. Bromides may be combined with the chloral or chloretone. If the spasms and pain are not controlled by these, morphin hypodermatically may be given. Enough of these drugs should be used to keep the patient quiet and give him sleep. Not dosage but effect should be the guide. As the disease progresses, spasm of the glottis and respiratory muscles must be relieved or death from asphyxia will result. Amyl nitrite should be kept in readiness to meet this emergency. A drop or two should be applied to the nasal mucous membrane when necessary. When the spasms still remain uncontrolled the inhalation of chloroform must be resorted to to preserve the patient from exhaustion. Often the chloroform must be continued for hours, the maximum dose being timed so as to control each oncoming spasm. The patient should be kept in a quiet darkened room and his nerves protected from every possible irritation.

Uncontrolled spasms of the muscles of respiration ends in asphyxia and death. Sauerbruch (Münch. Med. Woch., Oct. 6, 1914), in the case of a boy asphyxiated by spasms of the muscles of the thorax and diaphragm, severed both phrenic nerves through incisions along the posterior margin of the sternomastoid muscles. Artificial respiration, which had before been impossible, could then be performed, and with oxygen inhalations the boy recovered without inconvenience from the division of the nerves. This procedure is entirely unnecessary if intratracheal intubation can be done after the method of Meltzer.

T. Kocher showed that the insufflation of oxygen through the intratracheal tube overcomes the respiratory paralysis. The ears should be stopped with cotton wool. The food should be easily digested and nourishing, chiefly milk and eggs, and if necessary should be given through a rubber tube between the teeth, through the nares, or a tooth may be extracted to provide a space for feeding.

Elimination of the toxins is largely through the kidneys; for this reason the activity of these organs should be insured. The patient should be encouraged to take much of fluids. Saline solution is of decided help. It may best be given by rectum. The normal salt solution is employed; it is best injected slowly, two hours being given to inject 500 to 1000 c.c. A daily movement of the bowels should be had. Glycerin enemas are effective for this purpose.

Other Methods of Treatment.—Phenol was first extolled as an agent of therapeutic value against tetanus by G. Baccelli in 1888. It undoubtedly has some efficacy. Patients suffering with tetanus have a great toleration for phenol. It is possible that it acts as an antiseptic in inhibiting the growth of the organisms, or as an analgesic. It possibly diminishes the reflex excitability of the spinal cord and neutralizes the toxins. It is administered subcutaneously along the side of the spine. It must not be given too concentrated as it coagulates albumin and is not absorbed. A 2 or 3 per cent. solution is best used in tetanus. This should be injected at two- or three-hour intervals so arranged that 0.2 to 0.7 Gm. (3 to 11 grains) are given in twenty-four hours. Baccelli has given as much as 1.5 Gm. (22 grains). It is rapidly eliminated. Upon the first appearance of smoky urine the injections should be discontinued until the urine again looks normal. This phenol treatment does not interfere with the use of antitoxin or other treatments. The treatment may be continued for several days.

Sodium persulphate has given good results when injected intravenously. The solution must be freshly made with double distilled water, and kept protected from the light. The dose is 20 c.c. of a 5 per cent. solution. This dose may be given twice or thrice daily. Antitetanic serum should alternate with it.

Magnesium sulphate is used to allay spasms. It may be used in connection with the antitetanic serum treatment. Subdural injections of magnesium sulphate were advocated by S. Meltzer, who showed the power of this drug to inhibit nerve impulses when applied to nerve tissue. It has no specific effect upon the disease but it does relieve the most distressing symptoms. When injected into the subarachnoid space of the spinal canal it causes sensory and motor paralysis of the nerves of the cord. Care must be taken that the solution does not mount up to the base of the brain and produce paralysis of respiration. But a small amount can be used. In bad cases with strong opisthotonos it is best that the injection be preceded by moderate general anesthesia with ether or chloroform, which should be discontinued as soon as the injection is made. One injection controls convulsions for a day or a day and a half. Several hours may elapse after the injection before the paralysis appears. The injections may be repeated in twenty-four hours when necessary. This treatment may be relied upon to take the place of narcotics and sedatives.

Intraspinal injections of magnesium sulphate are best given with a 25 per cent. solution, of which 1 c.c. may be given for every 9 kilos (20 pounds) of body weight. The injection should be made in the lumbar region in the usual manner with the patient on the side as for anesthesia (see page 155). The patient should then be placed on his back. Relief from spasms should soon appear, and last for twenty-four hours or longer. As the muscles regain their power, another injection should be made before the spasms are fully developed. The second dose should not be as large as the first—about 0.8 c.c. per 9 kilos (20 pounds). Paralysis of the bladder is apt to be present and require catheterization. Weakening or stopping of respiration should be watched for. It is due to the salt mounting too high. When it occurs, a needle should be inserted in the lumbar canal, and some of the fluid drawn off, and then the canal should be washed out several times with Ringer solution. The upper end of the bed should be elevated, and intratracheal insufflation should be given.

In young children the beginning dose should not be more than 0.5 c.c. of the 25 per cent. solution for every 9 kilos (20 pounds) of weight. The drug is much more dangerous in children than in adults.

Subcutaneous injections of magnesium sulphate are not effective in severe cases unless used in large doses. Small doses frequently given are of value. For adults, 1.2 c.c. and for children 0.6 c.c. of the 25 per cent. solution may be given for every kilogram (2 pounds) of body weight, 3 or 4 times daily. It should be begun at the first appearance of symptoms.

Intravenous injections are highly dangerous. They have been used in 6 per cent. solution given at the rate of 2 c.c. per minute and discontinued as soon as the respiration begins to slow.

Intramuscular injections have been used in doses of 2.4 c.c of 25 per cent. solution, combined with light general anesthesia to relieve pain.

To neutralize the poisonous effects of magnesium sulphate a 25. per cent. solution of calcium chloride should be at hand, and injected at the site of the magnesium injection.

Subdural injections of analgesics are also employed to relieve the painful symptoms. Morphin, 0.001 Gm. ($\frac{1}{60}$ grain), and eucain, 0.004 Gm. ($\frac{1}{15}$ grain), dissolved in 3 c.c. (45 minims) of water, are injected into the subarachnoid space after the withdrawal of 4 or 5 times that amount of cerebrospinal fluid. This operation may be repeated every day until the patient's condition is improved. The results are due to the beneficial effects of the analgesia and to the withdrawal of the spinal fluid.

The warm bath treatment of tetanus has been an empirical remedy since the time of Hippocrates. It was fully reported upon by Zechmeister (Wien. allg. med. Zeitung, 1864 and 1865; and Wien. med. Presse, 1866); Paul Guerche ("Balneotherapie dans le Tétanos," Pantoise, 1910) has described the treatment; and A. Rose (International Clinics, vol. ii, series 23) has more recently brought it up to date. This is perhaps a neglected measure. The continuous warm bath has the power of relaxing the muscles. It relieves the peripheral nerve ends of multiple stimulations by bringing the whole skin surface under an equable temperature influence. All of the peripheral vessels are caused to dilate. Elimination of toxic substances by the skin is greatly promoted. The nervous and muscular systems are quieted and soothed. The patient should be made comfortable, so that he may lie in a tub, relaxed and submerged except for his head. The temperature of the water should be maintained at 38°C. (100°F.). Reports of cases of tetanus, treated by this method, show good results. The patients have been most comfortable in the baths. Some remarkable recoveries are reported.

Italian surgeons have recently treated infected wounds in warm antiseptic baths and believe that this treatment prevents tetanus. The wound is kept constantly submerged in the solution. A 3 per cent. solution of hypochlorite or 1:2000 corrosive sublimate is used. Tetanus seems to be prevented and the wounds heal promptly.

Conclusions.—In the treatment of tetanus the error commonly committed is to modify the vigor of the treatment to the severity of the symptoms. It is not good surgery to defer the more active measures until the symptoms become severe. If treatment is to be of any avail it must be applied at once, as soon as the surgeon sees the case. To apply some treatment and then determine to wait with the intention of using more vigorous measures if perchance the symptoms become worse is bad surgery. When the symptoms become worse, it will be too late. Every case of tetanus is serious enough to receive the most vigorous treatment; and the case with an incubation period of ten days or less should receive such treatment from the very beginning when the patient has the first muscular stiffness even though he feels otherwise well. That is the time to give him the benefit

of excision of the wound, injections of antitoxin into the nerves and spine and saline infusions. To defer active measures until his sufferings seem to demand something heroic is worse than useless.

In **postoperative tetanus** the catgut has commonly been held at fault because sheep, from which catgut is made, suffer from a disease similar to tetanus; but there is no conclusive evidence that this surmise is correct. It is probable that the cause must be sought outside of the catgut. I have had tetanus develop in a patient operated upon on a dry and very windy day when the air was filled with dust, and have always felt that had a better exclusion of dust from the wound been secured the disease would have been prevented. The Germans say, "Die Kokken springen nicht;" but I am quite sure that they did on that day. In certain abdominal cases in which the wound is soiled with intestinal contents, Matas (Trans. Am. Surg. Assoc., 1909) has shown that tetanus may come from uncooked vegetables recently ingested. This would indicate that to avoid the disease in such cases, the intestine should be thoroughly emptied and only cooked foods taken for three days before the operation.

The treatment of **head tetanus** is the same as that of other forms. **Fourth-of-July tetanus** is an American institution whereby for many years several hundred children each year lost their lives through wounding their dirty hands with blank cartridge wads. By a campaign of education, carried on by the Journal of the American Medical Association during ten years the number of deaths from tetanus, contracted on the Fourth of July, was reduced from 405 to 10.

The **prognosis** after treatment depends much upon the length of the period of incubation and somewhat upon the method of treatment employed. The mortality of all cases is about 65 per cent. Cases with an incubation period of less than eleven days are called acute cases. In acute cases, even under treatment with antitoxin, the mortality in some series has gone as high as 93 per cent. Intraspinal injections have given a mortality of 57 per cent. in acute cases. Subcutaneous injections in similar cases have given a mortality of 79 per cent. The subacute cases show much lower mortalities —ranging from 22 to 50 per cent. The Italian surgeons report still lower mortalities from the phenol treatment.

GAS BACILLUS INFECTION

This condition is called *malignant gangrene*, *emphysematous gangrene* and *malignant emphysema*. Infection with gas bacillus occurs in much the same way as tetanus infection. It is due to anaërobic microbes, usually the *Bacillus aërogenes capsulatus*. The same sort of wounds which develop tetanus are prone to develop this disease. The prophylactic cleansing of the wound is the same as for tetanus. When the wound is not infected with other organisms pus is not produced. The disease should not be confused with anthrax and malignant edema which can be differentiated in twelve or eighteen hours by inoculating a guinea-pig. The gas bacillus seems not to grow in this animal. Also a smear may be stained with carbol-fuchsin and the short thick gas bacillus with its rounded ends distinguished from the slender bacillus of anthrax with its beveled ends.

As the gas bacillus is strictly anaërobic, free opening of the wound to the air is necessary. Multiple incisions should be made into the affected tissues. Many long rubber tubes with multiple openings should be inserted into every part of the infected tissue, and through these thorough drainage and antiseptic medication should be secured.

When the infection occurred in the extremities, amputation formerly was

done. Free incisions will usually suffice, and if necessary amputation may be done later. An *antitoxin* has been perfected which not only is curative but possesses prophylactic power. It should be used early in all cases.

It should be remembered that the gas often extends far beyond the zone of infection, and amputation may unnecessarily be done in tissues which are emphysematous but not yet infected.

These anaërobes are spore bearers and the spores are killed with difficulty. Materials infected by the discharges should be boiled or destroyed.

It was formerly thought that the injection of oxygen and air into the wound was useful. Hydrogen peroxide was once much employed. It is doubtful if these have any special value.

The hygiene of the patient is important. Fresh air and sunlight are most valuable. If possible the patient should be cared for out of doors, although this may be said of all wounds and infections. The chlorin method of treatment is very useful (page 242). French surgeons have had good results with ether as a wound application. After free incisions have been made, ether is poured into the wounds; and several times daily gauze, moistened with ether, is packed into the wounds. By carrying multiple tubes to the depths of the wounds injections may be made without disturbing the dressings.

An elastic band about the limb, tight enough to cause congestion but not pain or anesthesia, is reported as useful.

Among the other substances which have given good results when used for irrigation, injection and dressing may be mentioned *Morestin's mixture* (equal parts of alcohol, glycerin and formol), turpentine solution (1.5 c.c. in 100 c.c. of salt solution), *Menciere's solution* (1 Gm. benzoic acid, 5 Gm. guaiacol, 4 Gm. alcohol, and 1000 Gm. water) and the usual agents employed in wound infections.

ANTHRAX

The virulence of this infection depends much upon the resistance of the patient. Good nourishment and hygiene are essential in its treatment. In superficial anthrax excision of the local focus of infection is practised with success. This treatment has the disadvantage that the fresh resulting wound may become reinfected with anthrax. The best results have been secured by the excision method when the wound after excision has been treated with chlorin solution, phenol or tincture of iodin. This may still be regarded as the most satisfactory local treatment.

Good results have also been secured by circumscribing the focus with a ring of punctures of the actual cautery, thus setting up a barrier of inflammation beyond which the infection cannot pass. The injection of the pustule and surrounding tissue with phenol has been successfully employed, the drug being used pure or in dilution up to 5 per cent. The pure phenol is best injected in drop doses in different places, not more than 15 drops at a time being used. When diluted phenol is employed it is injected around the disease and also into the infective foci.

In recent years the tendency has been to employ the nonoperative treatment. The disease is kept covered with moist dressings of bichloride or a 2 per cent. solution of aluminum acetate or other antiseptic. Hot dressings serve best.

Fused zinc chlorid in dosage of 0.6 Gm. (10 grains) may be placed directly in the infected tissues and held there by an adhesive strip. This causes a slough of the infected area.

The vaccine treatment has given good results in some cases. If the organisms are found in the blood the prognosis is grave. As a result of the labors of Pasteur, Sclavo succeeded in making a serum which is efficacious in this disease. The mortality following the use of this serum is about 6 per cent. Some reports show it as low as 3 per cent. It is innocuous. The usual dose is 30 to 40 c.c., to be repeated in twenty-four hours if no improvement is observed. Some surgeons use it in larger doses. In severe cases as much as 150 c.c. may be given in divided doses. The injections are made subcutaneously or into a muscle. In bad cases the injection should be made into a vein. Pulmonary and intestinal anthrax are also treated by the serum injections. The serum is highly beneficial.

The *Bacillus pyocyaneus* is antagonistic to anthrax, and may be used for this purpose in treatment.

The intramuscular, subcutaneous, or intravenous injection of *normal beef serum* was found by R. Kraus and his associates to be the most effective cure. The dose is from 10 to 30 c.c. In very grave cases 40 to 50 c.c. may be given. The dose is repeated daily if necessary. The serum should be inactivated by heating twice for one-half hour at 56° C. before using. (Prensa Méd. Argentina, Dec. 30, 1916; and Aug. 20, 1917.) This method of treatment has given remarkably good results.

ACTINOMYCOSIS

When occurring in an accessible site the best hope for the cure of actinomycosis is the removal of the disease by knife or curette. If the disease is not too widely spread it should be treated as a malignant tumor and excised, care being taken to prevent further infection of the fresh wound. The wound should be left open to granulate, and, before applying the dressing, it should be treated with chlorinated lime, tincture of iodin, or with phenol and alcohol, or swabbed with 5 or 10 per cent. nitrate of silver solution. Ten per cent. solution of formalin in glycerin has been found useful. Amputation of arm or leg sometimes becomes necessary to save life. If complete excision of the whole disease can not be done, then partial resection is advisable.

Extensive disease which can not be excised should be treated by laying open all sinuses and cavities and thoroughly curetting away the disease down to uninfected tissue. The wound surfaces should be treated with silver solution and packed with gauze. The operation should be repeated as often as there is evidence of recurrence.

This treatment is applicable to the disease when occurring in the jaw, tongue, neck and skin. Abdominal actinomycosis when recognized is amenable to the same treatment. Deposits occurring in the liver must be freely exposed, curetted out and drained. When intestinal actinomycosis is too extensive for excision it can be curetted. These cases should not be regarded as hopeless, but treatment should be persisted in. The surgeon should bear in mind that the disease itself is not so serious, the high mortality being due to complications in the form of bacterial infections and interference with the functions of important organs. Actinomycosis of the lung is usually fatal because of its inaccessibility. When it reaches the pleura and binds the lung to the chest wall, it then becomes accessible. The surgeon can anticipate this process by turning back a flap of chest wall, producing adhesions to wall off the rest of the pleural cavity and in two stages attacking the disease of the lung with cautery and curette.

The internal use of iodide of potash has been employed traditionally for many years. It seems to be of value. The internal administration of cupric sulphate in doses of from 0.015 to 0.03 Gm. (¼ to ½ grain), increased

up to 1 grain, thrice daily, has been recommended by Bevan (Annals of Surgery, vol. xli). He also used a 1 per cent. solution locally.

MYCETOMA (MADURA FOOT, FUNGUS DISEASE OF INDIA)

Injections of tuberculin seem to inhibit the disease. Some successful experiments have been made with a vaccine.

No internal treatment is known that is effective. When the disease is discovered while yet confined to an isolated part, such as a toe, amputation of the toe or wide abscission of the diseased area may cure the disease. Usually it is not brought to the surgeon until much of the foot is affected. Then amputation of the foot or leg, well above the disease, is the only known treatment which has proved effective.

ORIENTAL SORE (ALEPPO BOIL, PENJDEH SORE, NASAL BOIL, BISKRA BUTTON, ORIENTAL BOIL)

This condition, found in camels, horses and dogs in the Orient, and probably conveyed to man by flies, is cured by intravenous injections of salvarsan. One or two injections are followed by healing in the course of a month or more.

GLANDERS

Glanders, occurring in man, is a most intractable disease notwithstanding that the causative bacillus is short-lived and easily destroyed by antiseptics and heat. Mallein is of diagnostic value, and it is to be hoped that a curative serum will be perfected. The treatment now adopted consists in opening the nodules and abscesses with the thermocautery and disinfecting them with chlorinated lime, phenol and alcohol, tincture of iodin, chlorid of zinc solution (15 per cent.) or other strong antiseptic or cauterant. Small nodules should be excised. This disease is easily transmissible, and the surgeon should exercise every care lest himself or others become infected. A number of laboratory workers have perished by glanders. Wounds should be kept widely opened, packed and dressed with copious antiseptic dressings. The vital resistance of the patient should be preserved by the best possible hygiene.

Experiments with the production of a vaccine are being made. Success with an autogenous vaccine is reported.

HYDROPHOBIA

The successful prevention of this disease is one of the triumphs of modern medicine, and is one of Pasteur's greatest gifts to humanity. All persons bit by rabid animals should be subjected at once to the prophylactic treatment. The Pasteur treatment consists in inoculation with an attenuated virus made from the spinal cords of animals which have been infected with the disease. The period of incubation in man is variable but usually the disease develops in the second month after the infection. The prophylactic treatment should be taken as soon as possible after the receipt of the infection. Most large cities now have Pasteur institutes or clinics where the Pasteur treatment is given. The treatment must be administered within two or three weeks. In infections upon the face the treatment must be given within a few days.

The use of **desiccated virus** is, perhaps, quite as effective or even more effective than the Pasteur treatment. The average time of treatment is shorter.

The wound made by a rabid animal, if seen while fresh, should be disinfected with some strong cauterant such as nitric acid. If seen after it has healed it should be excised and the cavity packed with antiseptic gauze. Neither of these operations should prevent the use of the Pasteur treatment. The dog that inflicts the wound should be confined and kept under observation. He should not be killed but should be allowed to die of the disease. The lesions in the nervous tissues often do not show in animals which have been killed. The dog to be feared is the one that has a listless expression, with altered voice and hanging jaw and tongue; he wanders about aimlessly, is restless, bites at imaginary objects, or sulks into a corner; often he displays an unusual disposition to lick his master's hand or face. It is a mistake to think that every dog bite should be cauterized. If the dog is not rabietic the treatment should be simply that of an infected wound. The important thing is that the dog be kept under surveillance. If he prove to be mad, or show signs of the disease, the one thing of supreme importance is to secure for the patient the benefit of the preventive treatment. Compared with this, any local treatment of the wound, no matter how radical, sinks into insignificance.

When once hydrophobia has developed in man, there is no effective treatment: the disease is fatal. Hydrophobia can be eliminated by a more thorough inspection and control of dogs by society.

SNAKE BITE

The snake bites which require treatment vary with the geographical distribution of reptiles. The poisonous snakes of North America are rattlesnakes, copperheads, moccasins, vipers, the coral snake, and the gila monster. New England is almost free from poisonous snakes, the rattlesnake being about the only one remaining. The copperhead is found in the middle and southern states. The coral snake is found in the southern states and the southwest. The moccasin is found only in the south. The gila monster is found in Texas and Mexico. In South America, Central America, Africa, Asia, and Australia are many poisonous snakes. In Europe the viper and adder are found. In India the cobra and viper cause several thousand deaths yearly. The bite of the serpent gives a sharp sting followed by burning pain. Usually two small wounds, sometimes only one, are to be seen, surrounded by an area of steadily spreading redness and swelling. The fangs of the snake sometimes become fixed in the tissues. They should be withdrawn.

The indications of treatment are: (1) to remove or destroy the poison at its seat of entrance, (2) to prevent or retard the entrance of the poison into the general circulation, (3) to neutralize the poison in the circulation, (4) to hasten the elimination of the poison, and (5) to support the patient.

The action of the snake venoms depends upon the size of the dose entering the circulation. Most venoms produce fatal paralysis of the vasoconstrictor nerve mechanism, the patient dying with much reduced blood-pressure. They also cause hemolysis and ruptures of blood-vessels with thrombosis and hemorrhagic spots. All of these changes take place in a few hours if the blood receives a large dose of the venom. To prevent this the first step should be immediate constriction of the limb to retard the return circulation between the wound and the heart. It is best to apply several constricting bandages, and one at least should be about the one-bone part of the limb. This constriction should not be so firm or continued so long as to produce gangrene. Its object is to retard absorption while elimination is going on.

The constriction should be relieved gradually as the state of the patient seems to warrant. The next step should be the rapid excision of the whole wound area with the view of removing *en bloc* as much of the poison as possible. Every minute saved in these steps is of value.

Having cut out the poisoned focus, the wound should be treated with permanganate of potash crystals or strong solution. In the absence of chemicals the actual cautery should be used. Calmette advises the injection of the tissues around the wound of excision with 20 to 30 c.c. (1 ounce) of a 1 per cent. solution of chloride of calcium, and dresses the wound with the same. In less severe cases 0.3 c.c. or 0.6 c.c. (5 or 10 minims) of a 10 per cent. fresh solution may be injected in ten or fifteen different places around the wound.

If the patient is not seen until swelling and local inflammation have spread widely, the swollen tissues should be freely incised to permit the escape of blood and serum containing the venom. Suction can be used to advantage if apparatus can be had. As soon as possible the patient should receive a subcutaneous injection of 20,000 units of antivenene. The antivenene or Calmette's serum is of great value in neutralizing the venom of the cobra and other colubrines. Unfortunately it is not of service in treating the poison of the viperines, to which class the rattlesnake belongs, because it is not antihemolytic. The antihemolytic power is destroyed by the heat used in its preparation.

Madame Phisalix (Semaine Med., Aug. 18, 1909) isolated an alkaloid from the skin of the salamander which seems to be antidotal to snake-venom.

The elimination of the poison may be hastened by free catharsis, the use of enemas, and the introduction of as much fluid into the circulation as possible, proctoclysis, intravenous infusion or hypodermoclysis. The general treatment should be aimed to preserve the strength of the patient and meet emergent conditions as they arise. Alcohol has no place in the treatment of snake bite; it has done more harm than good, and it still continues to do so. When a stimulant is indicated strychnia may be employed. Alcohol is a temporary stimulant which is followed by depression. As respiration fails and the blood-pressure declines, lowering of the head may be of service. Artificial respiration may become necessary. The body should be kept warm and vitality conserved by every means. Suprarenal extract, 1 c.c. of the 1 : 1000 solution, injected and repeated when necessary, would seem indicated. It should be borne in mind that the poison of serpents is eliminated quickly and the patient suddenly recovers; or it rapidly destroys life. Therefore time is of the utmost importance. To keep the patient alive by whatever means is the prerequisite. Active treatment and hope should be kept up until the end.

In India it is customary in case of bite of cobra or Russel's viper to apply a firm ligature immediately, infiltrate the whole region of the wound by injecting with a hypodermic syringe a solution of chloride of gold—0.008 to 0.015 Gm. ($\frac{1}{8}$ to $\frac{1}{4}$ grain) and then injecting intravenously 100 or 200 c.c. of antivenene. If venom intoxication appears, more of the serum should be injected. Concentrated serum requires a smaller dose.

BITES AND STINGS OF INSECTS

The bites of some of the common insects, such as **flies, fleas, gnats, bedbugs** and **mosquitoes,** cause only a local inflammation which soon subsides and requires no treatment unless some other poison than the natural irritating discharges of the insect is injected into the wound. It not infre-

quently happens that either the insect or the skin at the site of puncture is soiled with some virulent organism, such as streptococcus, and a serious spreading infection takes place. This requires the treatment such as is laid down for inflammations and infections. Insect bites may be prevented by bathing the skin with one of the volatile oils, such as wintergreen or peppermint, or by applying camphor solution, or washing with phenol soap. For **mosquito** bites phenol and alum are of value. Simply rubbing a mosquito bite with soap will often give relief. To keep away mosquitoes the essence of pennyroyal is of service; eucalyptus plant in the room serves the same end. Oil of cinnamon, 1 part, with spermaceti ointment, 8 parts, spread over the hands and face will prevent bites. Oil of cloves, oil of eucalyptus, or oil of pennyroyal answer the same purpose. The treatment of the uncomplicated bites is best by means of alkaline solutions such as bicarbonate of soda, or weak ammonia water. Camphor solution, chloroform, menthol, ichthyol, salicylic acid, ammonium carbonate, calcium chloride and phenol are also of use.

The stings of **bees** are characterized by the sting, which is barbed, being left in the wound. The **wasp** has a pointed non-barbed sting and can sting more than once. When the sting is left in the wound the wound should not be squeezed, as squeezing tends to drive it in still further; but the blister should be opened and the sting extracted. The venom of the bee is acid, and is best treated by lime water, bicarbonate of soda, or diluted ammonia water. When multiple stings have been inflicted the constitutional disturbances, arising from the absorption of venom and from the peripheral irritation, require to be met by appropriate measures.

The bites of the venomous **scorpions, centipedes, tarantulas** and **spiders** should receive much the same treatment as those of venomous serpents. Constriction should be applied to retard absorption of the poison; and the wound if seen in time should be excised. An antivenom has been prepared which promises to be effective, against scorpion bites.

Certain insects, such as the **tick,** burrow into the skin, and unless they are pulled out produce an infected sore. The **gad-fly** burrows into the skin and deposits its eggs, which hatch after a week or ten days, and result in a brood which produce a cellulitis or an abscess. The gad-fly is common in Central America and South America. The insect should be extracted; and the resultant inflammation treated with antiseptic applications. The **sand-flea** (Chigo), which is common in the tropics, burrows beneath the skin, particularly of the feet, to deposit its eggs. In removing the sac of the sand-flea, care must be taken not to rupture it as the eggs may be liberated and the inflammation extended. The use of some of the oils above mentioned is of value in preventing these insects from burrowing into the skin.

TUBERCULOSIS

The prevention of tuberculosis should not be alien to the interest of the surgeon. It devolves upon him to take a part in the great humane movement to inhibit the progress of this disease. Its prevention demands that the sputum of persons with pulmonary tuberculosis shall be destroyed and not disseminated where it may contaminate the inhalations and ingesta of others; people should sleep by night and work by day as much in the open air as possible; workshops and livingrooms should be lighted by the sun, well ventilated and not crowded; food should be simple and nourishing; the use of alcohol, tobacco and other drugs should be discouraged; tuberculous patients should be taught their danger to others; tuberculous animals should be destroyed; the best possible hygiene should prevail; and the social-economic

conditions, which make it impossible for many even with industry and intelligence to secure the simple advantages of air and food, should be corrected. It is a social disease, and its prevention requires social readjustments. It is up to society not to the medical profession.

Tuberculosis is a matter of inadequate resistance on the part of the body and infection by the tubercle bacillus. The body should be kept in the best state of physical resistance, and infective material should be prevented entrance. Acute and chronic diseases which lower the vitality even temporarily prepare the ground for tuberculosis. Syphilis and alcohol among the "civilized" peoples are the particular precursors of tuberculosis. The crowded tenements and shops of the cities breed the disease. Its enemies are fresh air, sunshine, wholesome food, and cheerful work.

Other conditions which must be guarded against as predisposing to the disease are traumatism of joints and bones, not sufficient to cause a dislocation or a fracture but producing only a traumatic synovitis, a periostitis or a strain of an epiphyseal cartilage. Slight traumatisms to soft parts are also predisposing factors. Meningitis, epididymitis, mastitis and inguinal lymphadenitis have been preceded by such injury. Tuberculosis develops at such places because they have had their vitality impaired. Direct infection takes place not only through the mucous membrane of the respiratory and gastrointestinal tracts but also through wounds and abrasions of the skin. In the latter infections, the lesion is prone to be localized at the place of entrance. These predisposing conditions should be guarded against. It is also incumbent upon the surgeon in dealing with this disease to destroy all tuberculous discharges. Indeed, there is a moral obligation, resting upon all persons having to do with tuberculosis, to destroy the tubercle bacillus. Excreta should be disinfected and dressings should be burned. Boiling kills the tubercle bacillus. Phenol in 5 per cent. solution destroys it. Bichloride of mercury and formaldehyde act upon it but slowly. The disease could be eradicated utterly from the face of the earth; and now could be much reduced were it not for the fact that a privileged class of society profits by the conditions which keep it going.

The treatment of the patient afflicted with tuberculosis rests upon the following principles:—He should be restored to the conditions of living which would have prevented the disease; the diet should be the most nourishing possible without overtaxing the digestive organs or the emunctories; he should have fresh air day and night; he should live in an environment disinfected by the sunshine; he should have muscular rest and relaxation if tired or if fever is present; his mind should be occupied with some wholesome interest; and he should be infused with hopefulness. Tuberculosis develops in those whose vital resistance has been weakened by violations of the simple principles of hygiene; it is cured by restoring the patient to the conditions of living which, had he not forsaken them, would have prevented the disease. In addition to these hygienic principles, surgery aims to assist in the recovery from tuberculosis by removing the tuberculous focus, disinfecting it, insuring it rest, or by applying such local treatment as shall aid nature in overcoming it. Tuberculosis which is amenable to such local treatment is called surgical tuberculosis. In surgical tuberculosis there is the same need of hygienic treatment as in the non-surgical variety, for tuberculosis, neither local nor general, will develop in a body which presents a sufficiently high degree of vital resistance or good health.

Diet.—There is no specific diet or food for tuberculosis as is commonly believed. Cod-liver oil, milk, eggs, grapes, blood, etc., have all been employed as specific food cures, but their only merit is as simple foods, and

much harm can be done by an excess of any one article of diet. The food for the tuberculous should represent all of the necessary elements of diet: proteid, carbohydrate, mineral salts, water, and some fresh vegetable juices. These should be adjusted to the best economy of the body. The maximum nutritive requirements of the body should be satisfied, but excessive nourishment beyond this is not necessary. The gastrointestinal tract should furnish to the blood an abundance of nutritive material so that every demand of the cells for nourishment shall be filled, but it is unwise to overtax the digestive apparatus or the eliminative organs. The food should be simple, digestible, and nutritious. It should be eaten slowly, and be well masticated and salivated (see Nourishment, page 19).

The proteids are best supplied by milk, eggs, and the legumes. When meat is eaten it should be masticated until it becomes fluid and disappears in the mouth without a voluntary act of swallowing; fibers and pieces of meat that can not thus be resolved into fluid should be ejected. Most people, who say that they can not take milk, can, if they try. Such psychic prejudices in people who can not take even a small amount of milk are often overcome if they compel themselves to take a pint or more at a time. Milk is best taken raw. The cleaner the milk the better. Children should be given "certified" milk in preference to milk sterilized by heat. Most adults can take with their other food 2 or 3 liters of milk a day. Eggs should be taken raw or slightly heated (soft boiled). The many combinations of milk and eggs give a wide latitude for pleasing the palate with these two invaluable foods. Adults can consume with their other foods six to twelve eggs daily.

The legumes, as found in black beans and lentils, are good food. Potatoes and fresh vegetables, such as beans, lettuce, spinach, peas and beets are of value. In addition to these, some fresh fruit such as grapes, oranges, lemons, apples or peaches are good. Baked banana, dates, nuts without the skins, and cheese are nourishing foods. These things give variety to the diet; and, with the addition of dry bread and plenty of good butter, form an abundant dietary. The element in which the diet of tuberculosis should be most rich is animal fat, for the reason that it promotes leukocytosis and the destruction of bacteria. Animal fat is best secured in cream, butter, and the fat of meat and bone marrow. Butter should not be melted by being applied to hot foods, as it is thereby rendered difficult to digest. Fried foods should not be used; neither should complicated things such as pastries and puddings, nor richly sugared and spiced foods. It is better to eat four times a day, with meals four to six hours apart. Milk and raw eggs may be taken between meals. The old notion that we become hungry when the stomach becomes empty is not altogether well founded as the stomach contains food most of the time.

Fresh Air.—Fresh air is air in motion, having the approximate moisture-temperature ratio of the out-door air. It is essential for the cure of tuberculosis—as essential as it is for the prevention of tuberculosis. The patient should arrange to be out-of-doors every hour of the day. This is not difficult if he is willing to make his recovery the supreme object of his life. The roof, balcony, garden, veranda, fire escape, and the street are all a part of the out-of-doors. Even the tree tops may be taken advantage of. Sleeping out-of-doors is one of the great joys for the well; but it is a duty for the sick. For a general discussion of this subject see the chapter on Fresh Air in "Medical Sociology."[1] The fresh air which seems to be of the most advantage is that which contains the least of dust and smells. The

[1] "Medical Sociology," by J. P. Warbasse. D. Appleton and Co., New York, 1909.

air that comes across the sea seems to be especially pure. Tuberculous children particularly do better at the sea shore than any where else. The treatment of surgical tuberculosis at the shore has decidedly reduced the mortality. Dry air is of advantage because in a dry climate the patient is most apt to be out-of-doors. Dampness is not a disadvantage provided there is sunshine. An equable climate is of advantage because fluctuations in temperature mean changes of clothing and often a preference for the indoors. But if the patient will stay out, and the sun shines, a cold climate has decided advantages, because cold air is richer in oxygen, stimulating to the circulation, and invigorating to the nervous system. Usually patents are better off to remain at home in their own climate provided they can have the advantages which might be had elsewhere. No hospital should be guilty of the sin of keeping tuberculous patients indoors. Accessory treatment such as dressing of wounds, artificial hyperemia, etc., can be carried out in the fresh air.

Sunshine is of decided healing power in tuberculosis. There is not only advantage in breathing air that has been purified by it, and in inhabiting an environment which the sunshine has disinfected, but the rays of the sun have a positive bactericidal action, and tuberculous lesions are improved by being exposed to its actinic influence.

Sera and Vaccines.—The great hope for the tuberculous is the discovery of a serum or antitoxin which will be effective against the disease. Tuberculin has not fulfilled the hopes that were entertained for it. In some cases it is of benefit, but it can not yet be regarded as a specific treatment. It seems to be of especial value in certain early cases. It is being more and more employed. Especial skill and experience with its use are essential for good results. The technic is important. Most of the criticisms of tuberculin treatment should have been aimed at the method and not at the tuberculin. Some surgeons are now having tuberculin given by a skilled serologist in all cases (see Vaccine Therapy, page 255). Many surgeons are arriving at the conclusion that tuberculosis in all forms is best treated by tuberculin, heliotherapy, and hygiene.

Drugs.—Drugs are of value to counteract the complications of the disease in some instances, but they cannot be said to affect the disease itself. Creosote, guaiac and their compounds are perhaps valuable as antiseptics, but they are apt to do harm by irritating the stomach. Alcohol has done the tuberculous more harm than any other drug. Arsenic, the hypophosphites, iron and the iodides have all been much employed; it is possible for them to be of benefit; but they all have done more harm than good by disturbing digestion and detracting attention from the essential things. The hypodermic injection of mercuric succinimide in 0.012 Gm. (1/5 grain) doses has an inhibitive effect upon tuberculosis. Mercury can be said to be a drug which is capable of advantageously affecting the course of the disease.

Local Treatment.—The local treatment of tuberculosis should be conservative. The surgeon should guard against the mistake of focusing attention upon the local condition when the general condition of the patient is the thing of paramount importance. Where large bone areas have broken down the bone may be removed. Large accumulations of pus are best evacuated. But lesions which do not represent extensive destruction are best treated by local hyperemia, or heliotherapy.

Rest is essential for a part which is the seat of tuberculosis. It is often difficult to combine this with fresh air, but the two are necessary and must be combined. If moving the patient out-of-doors every morning disturbs the part, then the patient and the part had better remain out all night.

Splints and particularly the use of plaster-of-Paris enable the surgeon to immobilize tuberculous regions so that patients may be moved and dressed without disturbing the disease (see Tuberculosis of Bones and Joints).

Artificial hyperemia is of great value in the treatment of tuberculosis. It is obtained by constriction bandages or by suction cups (see page 229). In the treatment of tuberculous abscesses, Bier made a very small opening to evacuate the pus and applied the suction cup for three-quarters of an hour daily. In tuberculosis of joints the treatment by passive hyperemia for from three to twelve hours a day in most cases lessens the pain and hastens recovery. In treating the knee-joint, the leg below the knee from the toes up is enveloped in a snug flannel bandage and the constriction is applied above the knee. In treating joints, immobilization should also be employed. After operation for the removal of tuberculous bone or the evacuation of pus the resulting sinuses should be treated by suction. In few conditions are the advantages of suction hyperemia shown better than in the treatment of these sinuses and the small foci of infection which keep them open. Bier's treatment of tuberculous lesions, combined with outdoor air and other hygienic measures, has reduced the necessity for operative interference manifold. Tuberculosis of the lungs, often a complication of surgical tuberculosis, is also amenable to treatment by suction, which is applied by means of a mask, a simple nose and mouth mask with valves, which imposes an obstruction against inspiration.

Other means of producing hyperemia have been successfully employed and may still be used when the Bier method is not available. The use of hot compresses, followed by cold, and large warm fomentations are of service (see page 233). Irritation for producing local congestion is applied with iodin or other rubefacients. These measures have been quite superseded.

Light treatment for tuberculosis has proved most valuable. Sunlight is used. How deeply its actinic rays penetrate is not known, but we know that they are capable of decidedly benefitting tuberculosis. No results in treatment have ever been attained which equal those of the heliotherapy of Rollier at Leysin, who was trained in surgery under Kocher, and who restricted operation to the simple puncture of abscesses. He secures a cure in over 80 per cent. of the worst cases of surgical tuberculosis, including a majority of spondylitis cases, joint tuberculosis, peritonitis, nephritis, and cystitis. These wonderful results were attained in the outdoor sunshine, with the naked bodies of his patients exposed to the cold of winter and the warmth of summer. Finsen separated the chemical rays by refracting apparatus and then concentrated them upon the disease with good results. The *x*-rays are also of value in treating superficial tuberculosis, particularly lupus (see Heliotherapy and *x*-rays, Vol. III).

Drugs, used locally, are often useful. Notable for their antituberculous power are iodoform, chlorinated lime, formalin, chloride of zinc, balsam-of-Peru, cinnamic acid, ichthyol, camphorated naphthol, iodin, phenol and mercuric salts. Iodoform is the most used. For injecting abscesses and cavities, it is best used in a 5 or 10 per cent. suspension in glycerin or oil. The iodoform is left in the cavity and is absorbed so slowly that poisoning is not apt to occur. As much as 100 c.c. (3⅓ ounces) of a 5 per cent. mixture may be used. Where but a small amount of iodoform is used it need not be so much diluted; it may be used pure or mixed with equal parts of olive oil, or combined with ether and other antiseptics. It is also of value for injection into tuberculous soft tissues. Chloride of zinc solution and cinnamic acid in emulsion are injected in the same way. Camphorated naphthol is also injected into tuberculous foci. The advantage of these interstitial injections

depends largely upon the irritation and consequent hyperemia which they produce and not so much upon any specific bactericidal virtue.

Formalin-glycerin was recommended by J. B. Murphy as an injection for tuberculous cavities. He had good results with it in acute and subacute joint infections. The preparation is made by adding 0.6 c.c. (10 drops) of formalin to each 30 c.c. (1 ounce) of glycerin. This 2 per cent. solution is placed in a glass-stoppered bottle, shaken and sterilized under pressure. A solution more than twenty-four hours old should not be used. Extension is applied to the affected joint. Under general anesthesia and careful asepsis, the joint is injected. In the case of the knee the needle is entered behind the outer edge of the patella. Fluid is aspirated from the joint, and about 15 c.c. (½ ounce) of the solution slowly injected. Motion and massage of the joint should be used to distribute the fluid. A dressing is applied and the extension continued. The patient needs an injection of morphin for the pain. This must be repeated in a few hours. Swelling lasts four or five days. The extension may now be omitted and passive motion and massage given. From two to five injections are required at intervals of about two weeks. After the last injection the patient uses crutches for about six months.

Operative treatment of tuberculosis is applied when all of the disease can be excised; when there has been extensive destruction of tissue, leaving débris too abundant for absorption; when the general condition of the patient demands immediate relief from toxemia; when the infection is complicated by mixture with other organisms which alone would demand operation; when the destructive process threatens the invasion of important structures or viscera and must be checked; when excessive pain from pressure demands relief; and when conservative measures have failed. Small tuberculous foci may simply be exposed by incision and treated with iodoform powder or other antituberculous germicide. It is a common practice to curette out such foci. Usually this practice is safe enough, but if the disease is rather acute it is possible to drive the bacilli into the lymph spaces or blood-vessels and cause secondary infections or an acute extension of the disease. To obviate this the cautery is better than the curette. The treatment of tuberculous lesions in the various structures and organs will be described under the appropriate heads (see the surgery of the various structures and organs).

Tuberculous abscess which is small, not tense, does not threaten to rupture through the skin nor invade important structures, and is not interfering with the other essential treatment of the disease, need not be evacuated. Under other circumstances it is usually best to practice aseptic aspiration. This should be done with every precaution to prevent the abscess becoming contaminated with any organism besides the tubercle bacillus. The cleansing of the skin and the sterilization of the materials should be rigid. A large-sized aspirating needle or a small-sized trocar and cannula should be used. The needle should be introduced diagonally so that it passes through some distance of healthy tissue. If there is a soft place in the skin this should be avoided because of the danger of necrosis of the skin. The operation can be done with local anesthesia. Often the pus does not run freely because the needle becomes stopped with necrotic débris. This can be dislodged by passing in a wire or by injecting some fluid. The walls of the abscess should not be traumatized by squeezing. After the pus has stopped flowing, the cavity should be washed out by repeatedly injecting through the needle warm saline solution and allowing it to run out until it returns clear. The cavity should then be injected with iodoform mixture in sufficient amount to fill it but not to make it tense, provided that not more than 100 c.c. (3⅓ ounces) of a 5 per cent. mixture are used in an adult. The needle is

then withdrawn and the puncture spot covered with a bit of gauze. Among the various iodoform mixtures none is more effective than the following: iodoform, 5 Gm.; ether, 10 Gm.; guaiacol, 2.5 Gm.; creosote, 2.5 Gm.; and sterilized olive oil, 100 Gm. The guaiacol and creosote may be omitted. This operation must usually be repeated several times before a tuberculous abscess is cured, and then the cure must depend upon the healing of the causative focus or the death of the tubercle bacilli. (A prognosis may be arrived at by injecting a guinea-pig with some of the pus to discover if it contain living bacilli.) After ten days or more it will be observed that the abscess is again filling, and the aspiration must be repeated. At each operation it will usually be found that the size of the abscess is becoming smaller. When this treatment is once begun the abscess should never again be allowed to become tense with pus.

Bier successfully treated these abscesses by evacuating the pus through a small puncture incision, and then applying the suction cup for forty-five minutes daily, the suction being discontinued for five minutes every three minutes. If the abscess involves an extremity, passive hyperemia by means of the rubber bandage should be induced (see page 229). The bandage should be used two or three hours daily. This treatment may be combined with iodoform injections.

Small tuberculous abscesses may often be cured by dissecting out the whole abscess, without rupturing it, as a cystic tumor, and closing the wound. Another effective method is to lay open the abscess freely, cauterize the interior with pure phenol, followed by alcohol, and apply a firm dressing.

An abscess which is not curable by aspiration, incision or puncture and suction, and in which radical measures seem indicated, may be laid open by free incision, washed out and its walls and tuberculous foci thoroughly curetted. This operation is to be done only when the abscess involves the primary tuberculous focus which caused it. It should not be done if the abscess has wandered or burrowed away from the causative disease and simply represents a collection of pus without an infective nidus, as is the case with abscesses secondary to joint disease, deep visceral disease, or remote bone tuberculosis. In doing this operation, pockets and offshoots should be looked for. If a narrow constriction is found connecting the abscess with another cavity the constriction should be divided freely so that the two are thrown together. The curetting of a tuberculous abscess is best done with an irrigating curette. When every bit of the wall has been curetted, irrigation with hot or cold solution should be continued until hemorrhage has stopped; the surface should then be dried and packed with iodoform gauze. The wound may be partially closed by suture. This operation and the subsequent dressings must be done with the strictest asepsis. If the skin overlying the abscess has become thin and dark it is apt to become necrotic and increase the scar, and had better be cut away.

Sometimes the abscess wound after curettage may be sewed up, leaving only a place for the exit of the gauze drainage; and when the gauze packing is withdrawn a compressing dressing may be applied with the hope that the walls will grow together. Often after such a treatment the walls will not adhere everywhere but a smaller abscess will reform. This may be cured by subsequent treatment.

Tuberculous fistulas yield to the injection under pressure of iodoform-ether-oil mixture or iodoform and glycerin, after the fistula has been cleansed with salt solution; or bismuth paste may be used.

SYPHILIS

Syphilis is one of the most destructive of diseases. It is due to the *Treponema pallidum*, a *spirochete* which gains entrance to the blood. Venereal sores should be examined for the presence of these organisms. They can be found in most cases, and the diagnosis and justification for active treatment established. Syphilis is the only disease which attacks every tissue and organ of the body. It is the great cause of the grave nervous diseases. It has, probably, deteriorated the human race more than any other known disease. It is most commonly acquired through sexua intercourse.

The *prevention of syphilis* must first be through better teaching concerning sexual hygiene. Ignorance of sexual hygiene and of the meaning of venereal diseases should be met by better educational methods. If people were taught these vital things as much as they are a thousand matters of lesser importance, and if perfect economic freedom existed along with sexual liberty, syphilis would become a rare disease.

The prevention of syphilis is more an economic question than a moral or medical one. Still in the presence of the ignorance and economic injustices which promote disease, something can be done in a medical way to prevent syphilis. A 33 per cent. calomel ointment prevents the propagation of the spirochæta pallida. The parts which have been in contact with the syphilitic parts of an infected person should be cleansed and then well smeared with this ointment. The ointment applied before the infective contact and also after the infective contact is the best guarantee. Large experience shows that this is an almost certain preventive. It is employed largely by armies and navies.

Syphilitics should be warned of the danger of infecting others. The inoculation of syphilis requires that the discharges from a syphilitic sore or the blood of a syphilitic shall enter a wound or abrasion. Medical men in examining syphilitics should protect their fingers with rubber cots or gloves. Care should be taken in public places lest infection be conveyed by common utensils, such as drinking cups, spoons, and barber's razors. Cigars, pipes, penholders, pencils, dental instruments, and surgical instruments have all conveyed syphilis. The kissing of helpless children by syphilitics is not an uncommon mode of infection. The kiss of love is one of the commonest means of infection. Prophylaxis requires that the nature of the disease should be understood and the avenues of infection guarded against. When such an infective contact has taken place, pure phenol, tincture of iodin or other strong antiseptic should be applied at once. Calomel in a strong ointment has the power to destroy the virus of syphilis when superficial, but it is not penetrating.

Before inaugurating treatment, the diagnosis of syphilis formerly depended upon the appearance of the chancre and the constitutional symptoms. It is now possible by blood-serum agglutination tests and by identifying the spirochetes in the sore, to discover the disease before the constitutional signs have appeared and also to determine the presence of the disease when the constitutional signs have subsided or are uncertain. It will be but rarely that treatment will be begun before the chancre and primary eruption appear, but that it is possible should not be lost sight of. Even before the Wassermann reaction becomes positive, which is during the first week, or even before a colloidal gold reaction can be secured, the diagnosis may be made by discovering the spirochetes in the sore. By these means of diagnosis much time is saved in promptly attacking the disease with treatment.

Commercial greed, for business profit, and ignorance have been responsible for deceiving the syphilitic with the hope that he could be cured without potent measures. One of the penalties visited upon society for harboring the cults which offer prayers to extranatural powers for relief, and which look to the imagination for the removal of infective parasites, is the awful fate to which they condemn the syphilitic who falls under their influence. The disease can be cured; and unless it is cured it not only goes on with its insidious destruction, but it makes the victim a constant menace to society and a plague-spot in the community. On the other hand, an enormous number of people who are free from the disease are treated for syphilis by mercenary quacks and ignorant practitioners.

Excision of the Chancre.—The site of the chancre at one time embraced all of the infection. It was there that the syphilis germinated. But even after the disease has diffused itself through the system the primary focus continues to give off infection. The first thing to do after making the diagnosis of syphilis is to excise the chancre if it is still in a state of inflammation. This can be done under local anesthesia. It also enables the surgeon to confirm his diagnosis by microscopic examination.

Hygiene.—The general hygiene is most important in the treatment of syphilis. A person who has not lived hygienically should begin to when he contracts syphilis. If he has been in the habit of using tobacco and alcohol he should stop. This is imperative. It is difficult to cure syphilis when either of these poisons are being used. If nephritis is present it should be given attention. The teeth should be put in order and the hygiene of the mouth looked to. The cleanliness and health of the skin is important. Any vicious habits such as overeating, inadequate mastication and salivation, improper dietary, or insufficient fresh air should be corrected. Fresh air is important for the syphilitic as it is for the tuberculous. Sexual intercourse should be interdicted. Success in the treatment of this disease depends upon the treatment of the whole patient as much as upon the treatment of the disease itself.

The patient should be instructed in the dangers of infecting others and how it can be prevented. He should have the nature of his disease explained to him; he should be told that it is curable, that the cure depends upon the faithful observance of instructions, and that active treatment must be kept up for two years, general treatment for two years longer, and that he must be under medical supervision for the rest of his life. The virulence of syphilis is very variable, depending largely upon the patient's general health and upon hereditary immunity. In so-called civilized communities, all persons are more or less immunized by virtue of the syphilization of their ancestors. Among peoples whose ancestry has been free from the disease its virulence is frightful.

Drugs.—There are two treatments which are recognized as effective: (1) mercury and iodin, and (2) salvarsan and its allies. (3) Other drugs have a less potent effect.

Mercury was the first effective remedial agent found for the cure of syphilis. It has the power to cause the destruction of the Treponema pallidum in the living body. Salvarsan, discovered by Ehrlich, has the same power.

Treatment should be administered as soon as the diagnosis is positively made, but not before. No one should be started upon a course of treatment before the diagnosis is positive, simply upon the suspicion that he may have syphilis. Before the tests of Wassermann and Noguchi made possible the almost positive diagnosis of syphilis, the surgeon did not dare to begin

treatment upon presumptive evidence when the signs that were present might fade away and the patient be condemned to a lifetime of syphilitic treatment and vigilance, perhaps, without having the disease; and if he had the disease, and treatment was prematurely begun, as his symptoms disappeared the treatment was in danger of suffering the relaxation of uncertainty. Then it was best that lesion after lesion be permitted to manifest itself rather than take the chances of condemning a non-syphilitic to the diagnosis of syphilis. Now treatment is begun as soon as the organisms are found in a lesion or a positive blood reaction of syphilis is obtained. Without this, the surgeon should wait as of old until the positive signs of the disease have appeared, to confirm absolutely the diagnosis, before beginning the treatment.

Mercury is administered by mouth, by inunctions, by hypodermic injections, by inhalation and by intravenous injection. The dose of mercury should be enough to control the disease.

It should be the largest amount possible which does not have a deleterious poisonous effect upon the patient. Too much mercury may cause symptoms which may be mistaken for those of syphilis. General debility, loss of appetite, languor, anemia, loss of weight may be caused either by syphilis or by mercury. When doubt exists the mercury should be discontinued for the sake of orientation. When symptoms of the disease are subsiding and the patient is in apparent good health, and when no further symptoms appear after all signs have subsided, the surgeon may know that the dosage of mercury is right. But this dosage varies with different individuals and with the same individual at different periods of the disease. The treatment of syphilis demands the application of intelligence and watchfulness.

By the mouth, mercury is given as the method of choice when the disease is not fulminating, when a sufficient amount can be taken and when the stomach is free from irritation. If the patient's appetite fails and he shows other evidences of gastrointestinal disturbance or the disease is not controlled, the treatment by mouth should be replaced by inunctions or by injections. It is best to begin with a moderate dose, increase it until the gums or teeth begin to be a little sore and then drop back to one-half the dosage producing these symptoms. This is the patient's average dose.

The yellow mercurous iodide (*Hydrargyri iodidum flavum*) is the best form for gastric medication. It should not be given with soluble iodides as the more poisonous biniodide results. The drug is given in tablet form, 0.02 Gm. ($\frac{1}{3}$ grain), two hours after each meal. This should be increased to 0.2 or 0.25 Gm. (3 or 4 grains) daily. Sometimes if colic and diarrhea result, the patient can take the drug combined with chalk. In some cases the bichloride (*Hydrargyri chloridum corrosivum*), in doses of 0.003 to 0.006 Gm. ($\frac{1}{20}$ to $\frac{1}{10}$ grain) is better tolerated.

The patient who tolerates mercury by mouth should be kept along on the dosage which inhibits the appearance of symptoms and which keeps the patient feeling well. This should be continued for one or two years with one or two days of intermission in each week. At the end of two years the treatment should be intermitted for one week in each month during the third year. During the fourth year the treatment should be given every other fortnight. Then for the next four years it should be given for a month every spring and fall. At any time during all this period if symptoms appear the continuous treatment should be resumed and the patient treated as though the disease were in the first year. At the end of mercurial treatment the patient should be always under observation for the appearance of late manifestations of the disease.

By inunctions, mercury may be given without irritation of the stomach or bowels, and it is, aside from the trouble entailed, the most satisfactory way of giving the drug. This is the most popular mercurial treatment in Europe; it is comparatively little used in America. The oleate of mercury (*hydrargyrum oleatum*), reduced to 5 or 10 per cent. strength, is the most cleanly but most expensive application. Four Gm. (1 dram) daily of the diluted oleate or of mercurial ointment (*Unguentum hydrargyri*) is used. The method found most satisfactory consists in having the patient take a hot bath, after which the skin is well dried and the ointment rubbed in for five minutes. The area for inunction should be about twice the size of the hand. The sides of the chest, axillæ, abdomen, lumbar regions, thighs and legs are used. After rubbing in the ointment an undershirt or drawers are put on to protect the night clothes from becoming soiled. The usual morning bath should be taken. The undergarments used at night may be used without washing until the ointment begins to come through and soils the night clothes. Each succeeding inunction is applied in a different place to avoid irritation of the skin. It is customary to divide the trunk into six areas so that each area is returned to after six days. If dermatitis appears, each area should be used less often; or the ointment should be diluted one-half, and twice the amount used.

The regulation of the dose must depend upon the symptoms. Often it will be found that 4 Gm. (1 dram) daily does not suffice to cause a subsidence of the symptoms; in that event the dose should be increased to 2, 3 or 4 times that amount. The hot bath, which may be a hot-water, steam or air bath to promote sweating, serves to make the skin more absorbent and at the same time facilitates elimination of the mercury already absorbed. The vigor of the treatment must depend upon many conditions. Salivation should not be induced. During the first year it is customary to give a dram of the ointment every day for from six to ten days; this is followed by a discontinuance of the treatment for from three to five days. In some cases it will be found that even less than 4 Gm. (1 dram) a day suffices. Often it need not be given more than four or five days in succession.

During the second year, six days of inunction and six days of rest are customary; during the third year, six days of inunction and twelve days of rest; and during the fourth year, six days of inunction and eighteen days of rest. In the spring and fall of the third and fourth years the dose should be increased to the original amount for about a month. During the fifth year and for three more years thereafter, if tertiary symptoms have not appeared, the inunctions should be used for a month as at the beginning, twice yearly, spring and fall. The appearance of tertiary symptoms call for a continuance of the treatment for two years as applied during the second year. It is sometimes convenient to combine the inunction treatment with mercury by mouth either to diminish the dose of each or to intermit one or the other.

By intramuscular injections, mercury is given in exact dosage, the results are quicker than by either of the two preceding methods, and the whole course of the disease is under better control. This method is much used and is steadily gaining in popularity. Relief of symptoms is sometimes observed in a few hours. The general signs of improvement are usually apparent by the second or third day. Eruptions begin to fade away and primary, secondary or tertiary lesions show retrogression. Often later lesions, which have been intractable to mercury by mouth or inunctions, subside under treatment by injections.

The best form of the drug for this treatment is the *salicylate of mercury*. This salt is insoluble in water, but slightly soluble in weak alkaline and so-

dium chloride solutions. It contains about 59 per cent. of mercury. When injected into the tissues it is slowly and continuously absorbed and acts as continuous medication for several days. This is entirely different from the old method of injecting soluble solutions. The treatment if properly applied is practically painless, and has the great advantage that it does not have to be given often. Salivation is rare; but if bad salivation does occur, it is but a minor operation to cut down upon the injected mercury and excise it The drug is best suspended in liquid petrolatum. A uniform suspension is secured by shaking the fluid. A 10 per cent. (by weight) suspension is used. This easily flows through the needle of a hypodermic syringe. Of this mixture, usually 0.3 to 0.42 c.c. (5 to 7 minims) is used. A large dose is 0.6 c.c. In urgent cases 1.2 c.c. (20 minims) may be given.

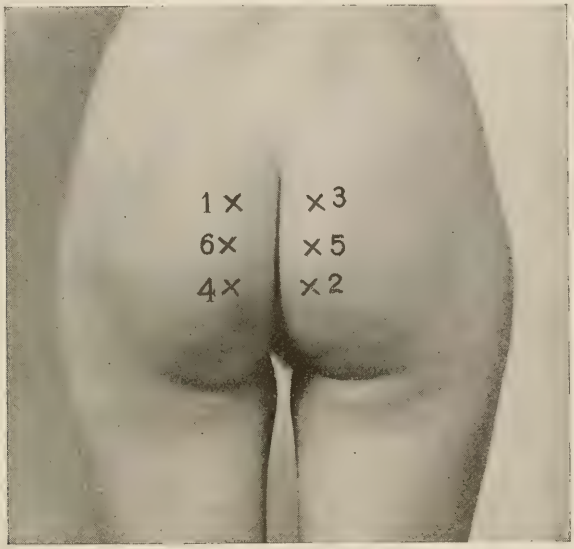


FIG. 175.—SHOWING PLACES FOR SIX INJECTIONS OF MERCURY SUSPENSION.

A popular mixture is 3 Gm. (50 grains) of salicylate of mercury, 2 Gm. (30 grains) of lanolin, and enough pure olive oil to make a total of 30 c.c. (1 ounce). In this mixture the drug represents one-tenth.

The best syringe is made of glass and metal. The drug does not corrode metal. The syringe should be free from water. The needle is plunged into the muscle of the gluteal region. The syringe should then be disconnected from the needle to see if any blood flows out. If blood flows, a vein has been punctured and the needle should be reintroduced in another place to prevent the danger of making the injection into a vein and causing embolism. It is best that the needle join the barrel by a friction connection in preference to a screw connection. The needle should be about 4 cm. (1½ inches) long. It should go through the fat layer and into the muscle.

Injection fluid needs to be sterilized but once. It is best put in a number of small bottles. Fifteen cubic centimeters (½ ounce) vials are good. Several of these with their corks are boiled and dried. They are then filled with the mercury suspension, stood up to their necks in a vessel of water and the water gradually brought to a boil. They are kept in this for an hour, then are allowed

to cool, the cotton is replaced by sterilized corks, the head of the bottles are dipped in melted paraffin to seal the corks, and they are ready for use. An occasional shaking keeps the mercury from packing in the bottom. When a bottle is opened it should be exposed to the air for as short a time as possible; but if care is used it is not necessary to resterilize it; using a sterile fluid does not necessitate boiling the syringe. If the needle is heated in fluid it should be in oil. It suffices to keep the syringe in a clean receptacle; before using, the tip which enters the needle may be sterilized by passing through an alcohol flame; the needle may be sterilized in the same way. Not enough heat to destroy the temper of the metal should be used.

The skin should be sterilized as for a surgical operation. The best place for injection is the gluteal region, but the intrascapular region may be used. The site of preference is the center of the gluteal mass. The order of injections is indicated in Fig. 175. By not going near the tuberosity of the ischium or trochanters pain upon motion or sitting is not experienced. The skin is last washed with ether or strong carbolic solution applied at the site of puncture for anesthetic purposes. The operation is done with the patient standing. The needle should be inserted quickly. If a vein has not been entered, the medication is then slowly injected. The needle should be withdrawn quickly. No dressing is required, or only a bit of zinc oxide adhesive plaster. The pain of the operation is but slight. There is no after-pain, only a sense of soreness or bruise lasting for a few days. If the operation is improperly done, the injection made too close to the bone, or the pelvic nerves involved, pain will result. Rarely the intramuscular injection will cause pain because of the accidental involvement of a small sensory nerve.

The injections are made once a week, and the treatment carried along and abated in the same ratio as in medication by mouth or by inunction.

Instead of the salicylate of mercury, *calomel* may be employed with liquid petrolatum or olive oil in 10 per cent. suspension. This mixture should be sterilized the same as the salicylate. The dose is 0.6 Gm. (10 minims), which represents 0.06 Gm. (1 grain) of calomel. In very urgent cases in which it is important that the progress of a syphilitic lesion be checked as soon as possible to prevent perforation or involvement of an important part, a soluble mercuric salt may be injected. For this purpose *mercuric chloride* (bichloride of mercury) is used. Three-tenths Gm. (5 grains) is dissolved in 30 c.c. (500 minims) of normal salt solution, and 0.6 to 2 c.c. (10 to 30 minims) of this injected into the muscle. This represents a dosage of 0.006 to 0.018 Gm. ($\frac{1}{10}$ to $\frac{3}{10}$ grain) of the drug. It must be injected daily as the absorption is rapid. There is apt to be considerable pain.

A less painful preparation consists of mercuric chloride 0.5 Gm. (8 grains) phenol 0.5 Gm., and physiologic salt solution 30 c.c. (1 ounce). One to 2 c.c. (15 to 30 minims) of this solution may be injected every other day with little pain.

Painless injections with *mercuric chloride* may be made if combined with a local anesthetic. If a 2 per cent. solution of quinin and urea hydrochloride and a 1 per cent. solution of mercuric chloride, both in distilled water, are separately heated to the boiling point and the two hot solutions mixed, they form a clear solution, which, if allowed to cool down to 43°C. (110°F.), may be injected into the muscles without pain. This should be given in doses of 1.2 to 3.6 c.c. (20 to 60 minims). Of this solution, 1.2 c.c. (20 minims) represents 0.006 Gm. ($\frac{1}{10}$ grain) mercuric chloride and

0.012 Gm. (1/5 grain) quinin and urea hydrochloride; and 3.6 c.c. (60 minims) of the solution represent 3 times those amounts.

Freshly made 1 per cent., solution of *benzoate of mercury* in distilled water with the addition of 2.5 per cent. of sodium chloride, may be injected daily in doses of 2 to 3 c.c. (30 to 45 minims) with very little pain.

A fresh solution of *mercuric iodide* 1 Gm., pure dry sodium iodide 1 Gm., pure saccharose 10 Gm., in 100 c.c. of sterilized distilled water makes an unirritating solution.

Other mercuric salts are the cyanide of mercury and biniodide of mercury. For *rapid effect*, perhaps, no treatment is so effective as mercuric chloride in doses of from 0.0032 Gm. (1/20 grain) to 0.0455 Gm. (7/10 grain) intravenously in salt solution.

Intravenous injections of mercuric chloride in doses of from 0.01 to 0.02 Gm. (1/6 to 1/3 grain) may be given with much success. Five or six such injections in salt solution are used. Benzoate of mercury in 1 per cent. solution as an intravenous injection has given good results. From 2 to 12 c.c. (30 minims to 3 drams) of this latter solution are used at dose.

Mercurialized serum is made the same as for intraspinal injections. It is less irritating than simple solutions. A more practical method is the use of whole blood as a vehicle for the solution, since there is no especial advantage in removing the cellular elements of the blood. For this purpose, the desired dosage of mercuric chloride is dissolved in 15 c.c. (1/2 ounce) of normal salt solution made with warm distilled water. A warmed syringe, holding at least 30 c.c. (1 ounce), takes up this solution, but no air. The needle should then be inserted into the vein and 15 c.c. (1/2 ounce) of blood aspirated into the syringe. Immediately without withdrawing the needle from the vein the mixture of blood and mercuric solution is slowly injected. By this method the irritating mercuric salt becomes fixed with albumin in the syringe before it enters the vein, and the injection becomes non-irritating. In the absence of salvarsan this is the most effective method for the intensive treatment of syphilis.

The *inhalation method* of Kromayer consists in inhaling finely divided mercury, placed between layers of mull in a face mask which is worn at night. The inhalation method known as that of Campailla consists in mercurial fumigation combined with diaphoresis in a small heated room.

The *mercurial bath*, in obstinate skin lesions was once much used. The patient is given a warm bath and dried off. He is then seated naked upon an open-bottomed chair. Under the chair are placed a pan of boiling water and a tripod supporting a metal plate, under which is an alcohol lamp. About 1.2 Gm. (20 grains) of calomel are put on the plate, the lamp lighted, and the patient and apparatus thoroughly wrapped in blankets in such a way as to confine the heat and vapor to the surface of the body. The lamp is allowed to burn for fifteen minutes, and after ten minutes more the patient goes to bed. About three treatments a week are given.

In many cases of syphilis, particularly in women, no single method will give the patient the necessary amount of mercury without undue irritation; and in such cases it is advisable to combine two or more different treatments.

Hydrargyrism, manifested by the appearance of salivation, is best avoided by regulating the dosage of mercury and by frequent inspection to discover its first signs. Persons taking mercury for syphilis should give much care to the hygiene of the mouth. There should be no decayed teeth which are unfilled. The teeth should be kept clean and the gums free from irritation. All such patients should be told of the meaning of ptyalism, and instructed to regulate the dose of mercury should salivation appear. Acute salivation

should be met by withdrawal of the drug for a time; but the early symptoms of soreness of the teeth and slight increase of saliva may be met by diminishing the dose. When ptyalism has developed *potassium chlorate* is the most efficient remedy. It is used in the form of a saturated solution. A teaspoonful of the salt is added to a glass of water, with which the patient should rinse his mouth every few minutes. It should not be swallowed.

If the salivation is pronounced, an astringent disinfectant solution should also be used. Boric acid and tannic acid, 4 Gm. (1 dram) of each to a glass of water (200 c.c.) are used as mouth wash. Atropin may also be used, its effect upon the pupil being watched. If ulcerated patches develop in the mucous membrane, they should be touched with silver nitrate solution (5 or 10 per cent.). The presence of cellulitis calls for a mouth wash of potassium permanganate (1:1000) or hydrogen peroxide. The patient in pronounced cases should be given hot sweating baths, laxatives, and much water for diuretic purposes.

Chronic hydrargyrism should be treated by withdrawal of the drug and the application of hygienic treatment.

Iodin is not an antisyphilitic. It does not kill the pale spirochetes nor even harm them. Its action is only to hasten the absorption and softening of inflammatory deposits and facilitate the elimination of mercury. Since the introduction of arsenical treatment, the iodides are used much less. It is only in chronic cases and after courses of mercurial treatment, that they are employed at all. *Potassium iodide* is the drug commonly employed. It should be begun at the end of the first eighteen months of the disease and should be continued for six months along with the mercuric treatment. The iodides are of little value in the early stage of the disease. The above rule, to give iodin at the middle of the second year, is excepted in secondary syphilis when the lesions are of the precocious type, resembling the tertiary stage, and the disease affects the bones, the nerve centers, the connective tissues, important viscera, or the deep parts of the skin. The iodides are to be given in all forms of tertiary syphilis. In primary and secondary syphilis, if the initial lesion becomes phagedenic, if syphilides become ulcerated, if there are infiltrations which are unusually large, or if deposits break down and ulcerate—if these conditions exist despite full dosages of salvarsan and mercury, iodides may be added to the medication. But it is in the older lesions that the drug is most effective. Aside from its direct effect upon the disease it is of value as a solvent of mercury, for which reason it is often wise during the first two years of mercurial treatment to omit the mercury for a while and give iodide. This plan saves the patient from the danger of being injured by mercury.

Iodide of potassium is given in a 50 per cent. aqueous solution. Ten drops (0.6 c.c.) of this represents approximately 0.3 Gm. (5 grains) of the drug. Milk disguises the taste. Some do not object to taking it in water. Syrup of tolu, syrup of orange peel or syrup of sarsaparilla are also used. The drug should be taken 4 times daily, an hour or more before or after meals. The beginning dose should be 0.3 Gm. (5 grains). This should be increased 0.06 Gm. (1 grain) every day until the maximum dose is reached. If no lesions are palpable 0.6 Gm. (10 grains) may be regarded as the maximum dose. After reaching this the dosage may then be dropped back to 0.3 Gm. (5 grains). If lesions or symptoms of lesions are present the dose should be increased until they disappear or until symptoms of iodism or intolerance are produced. If more convenient the drug may be prescribed in one of the above-mentioned vehicles, or in tablet form, to be taken with plenty of water. In the absence of symptoms it is wise to give a course of

iodide treatment for a few weeks from time to time so long as mercury is used.

Mixed treatment may often be advantageously given by combining the mercury and iodide in the same prescription. Such a combination is—*Hydrarg. iodid. rub.*, 0.25 Gm. (4 grains); Potassii iodid., 15 Gm. (4 drams); Syr. sarsaparillæ comp., 180 c.c. (6 ounces); of which a teaspoonful (4 c.c.) is to be taken in water 4 times daily. Bichloride of mercury in doses of 0.002 Gm. ($\frac{1}{32}$ grain) may be used in place of the red iodide. A tablet containing 0.16 Gm. ($2\frac{1}{2}$ grains) of potassium iodide and 0.002 Gm. ($\frac{1}{32}$ grain) of the corrosive chloride of mercury is of value. Two of these are taken two hours after each meal.

Iodism should be watched for. Care must be exercised in giving iodides to patients who have been under mercuric treatment. If the iodide is given too freely at first it may liberate an excess of mercury from the tissues and cause salivation. The appearance of symptoms of iodin poisoning, characterized by anorexia, malaise, and irritation of the mucous membrane of the eyes and nose, should be met by withdrawal of the drug. If the symptoms are mild and it is important that the drug be continued, tolerance may be secured by giving it with large quantities of water. Two to 4 Gm. (30 to 60 grains) or more of the iodide of potassium or sodium may be dissolved in 2 to 4 liters (2 to 4 quarts) of some pleasant mineral water and drunk during the twenty-four hours. Some patients who are affected unpleasantly by the potassium salt can take iodide of soda. A simple diet is essential in all cases. Often a draught of starch water will render iodide tolerable to the stomach.

With salvarsan treatment iodides are used in much smaller amounts than when mercury alone is given. It is especially in connection with the mercury therapy that the iodides are called for.

Salvarsan is the dihydrochloride of dioxydiamidoarsenobenzene, often called "606," discovered by Ehrlich. It is commonly given intravenously. The dose is prepared fresh for each injection, 0.6 Gm. of the drug being shaken up with 40 c.c. of fresh sterilized hot salt solution. This should be well shaken up with glass mixing balls. The solution thus made is acid and cloudy. It is essential that it should be alkaline when injected. For this purpose 1 c.c. of a 15 per cent. solution of sodium hydrate is added. The sodium hydrate should be added a drop at a time and the solution shaken after each drop until the fluid becomes clear. Then enough fresh hot salt solution is added to bring the total amount up to 300 c.c. Each 50 c.c. of this suspension contains 0.1 Gm. of salvarsan.

The water used should be *freshly distilled water*. It should be sterilized before making the solution and should be used within three hours after it has left the still. The solution should be used at once after it is made. In the preparation of the solution and of the patient the surgeon's hands should be clean and the operation carried out with strict observance of aseptic details.

The solution is used at a temperature of about 45°C. (113°F.). It is placed in a graduated burette, from which a rubber tube passes to a nozzle. This nozzle is provided with a stop-cock and fits into a needle. A platino-iridium needle is used, having a lumen slightly larger than the ordinary hypodermic needle. A temporary constriction is placed about the arm above the elbow to make the veins prominent. A vein at the elbow is selected. The skin over it is punctured with a sharp cataract knife, and through this wound the needle is passed through the wall into the lumen of the vein. The constriction about the arm should then be removed.

It is well to have a second burette of warm salt solution connected with the

tubing (Fig. 176). From this a little salt solution may be allowed to run into the vein to test the position of the needle. This is desirable, because, if the needle is not in the vein, salvarsan, entering the tissues, is painful, and may cause necrosis. Having determined that the needle is in the lumen of the vein, the salvarsan solution is allowed to flow slowly into the circulation. Not less than ten minutes should be allowed for the 300 c.c. to enter the vein. Then a little salt solution should be allowed to flow through to wash out the needle, and the needle should be removed. The rate of flow is regulated by the height of the burette and the amount of opening allowed by the stop-cock.

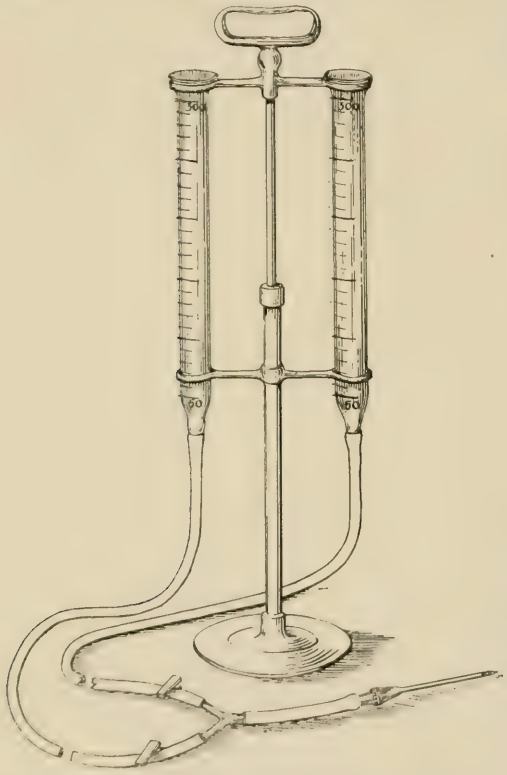


FIG. 176.—APPARATUS FOR INTRAVENOUS ADMINISTRATION OF SALVARSAN BY GRAVITY.
One vessel for drug, one for salt solution.

Instead of using gravity many operators prefer a syringe. By having a two-way cock, either salvarsan or salt solution may be used (Fig. 177).

If the vein is not easily reached it may be exposed by incision under local anesthesia as is done for transfusion. If the above simple procedure is carried out there should be but slight local soreness, and no immediate systemic discomfort suffered by the patient. After a few hours there may in some cases be some malaise, anorexia, chill, fever, vomiting, or diarrhea. Any of these symptoms which may appear have usually passed away in from twelve to twenty-four hours. Anaphylactoid reaction with syncope is best met by an immediate intramuscular injection of 0.3 to 0.6 c.c. (5 to 10 minims) of 1 :1 000 adrenalin solution. In from three to fourteen days the patient usually feels better than before the injection.

The *contraindications* to the use of salvarsan are scleroses of the cardiovascular system. In cases of aortitis, sclerosis of the coronary arteries, and myocarditis, it is contraindicated. In cases of acute or serious chronic nephritis it is not to be used. In advanced disease of the cerebrospinal system it must be used with caution. In persons who are greatly enfeebled; in alcohol, nicotine, or lead poisoning; in acute infectious diseases; in tuberculosis, advanced gastrointestinal disease, and pregnancy, salvarsan is contraindicated. By using mercury between the injections of salvarsan the danger of ill effects may be largely obviated. In all of these questionable cases, if salvarsan is used the dose should be 0.3 or 0.4 Gm. Some surgeons believe that salvarsan should not be given in the florid stage of syphilis or in the secondary stage, because of the danger of brain complications. Fatal myelitis occurs in some cases after the intravenous or intraspinal injection of salvarsan or neosalvarsan.

Exceptional disturbances have been noted following salvarsan injections. It should be remembered that arsenic is a poison and must be used with caution. It is undoubtedly possible that some of the symptoms of polyneuritis following salvarsan may be arsenical poisoning. Serious and often fatal central nervous disturbances occur, which are probably due to the rapid death of many spirochetes in important nerve centers and overwhelming of the tissues with their products. So serious is this that many syphilologists advise against the use of salvarsan in cases with fresh intracranial lesions. A large number of deaths have occurred in these cases.

If syphilitic lesions exist in the brain the first dose should be small (0.2 Gm.) or the salvarsan should be preceded by mercurial treatment because of this danger of the local inflammatory reaction arising from the rapid destruction of a large number of spirochetes at one location in the brain.

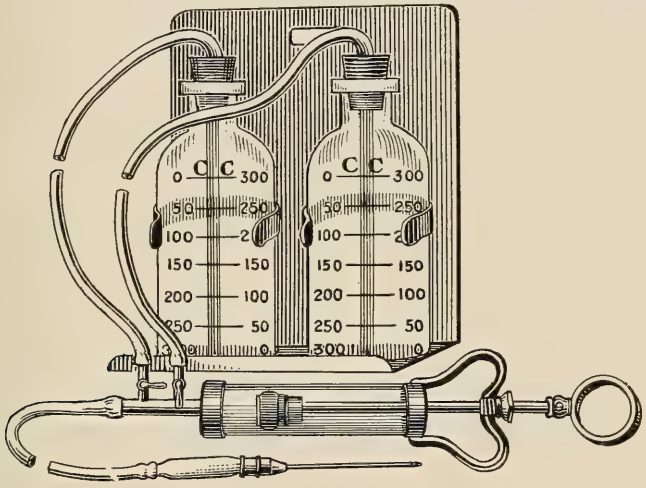


FIG. 177.—SYRINGE APPARATUS FOR INTRAVENOUS ADMINISTRATION OF MEDICATION
One vessel for drug, one for saline solution.

The *dosage of salvarsan* is 0.6 Gm. for the strong and 0.2 or 0.3 Gm. for the weak. The curative effect is proportionate to the size of the dose. The drug is practically all eliminated from the system in a week. At least six doses should be given in all cases. Recurrence of symptoms call for repeated injections. The drug kills spirochetes, but some which have become encapsulated in the tissues are not reached by it. These must be liberated by time. Mercury helps dislodge them. This is the reason for the combined treatment. In ordinary cases it is advisable to repeat the salvarsan in from seven to ten days. A third dose follows in two or three weeks, and a fourth dose in three or four weeks. Four doses will rarely produce a negative blood reaction. Six, or eight, or more doses are usually required.

Many surgeons give salvarsan in 150 c.c. of water instead of 300 c.c. Plain distilled water may be used instead of salt solution.

This drug is effective in all stages of syphilis. If it is used in full dosage and repeated at the end of a week, the maximum effect is secured. When used as soon as a diagnosis is possible, in the early stage of chancre, it is possible in some cases for a cure of the disease to be accomplished. The earlier the disease, the better the result. Salvarsan may abort syphilis if given early and associated with excision of the chancre. It is of especial

importance in patients who can not take mercury, or in whom mercury is not efficacious. Especially is it valuable in those cases which persistently show a positive Wassermann reaction after mercurial treatment. Cases in which there are mucous patches in the mouth or other lesions which cause danger of contagion to others may be rapidly healed by salvarsan. It is to be used promptly in the malignant forms of syphilis.

In the ordinary case seen so early (within one or two weeks after the first sign of chancre) that the Wassermann is negative and diagnosis is made by appearance of the sore or by finding the spirochetes the treatment should be as follows:—Two full doses of salvarsan should be given a week apart. The chancre should be excised. Five days after the last dose of salvarsan, intensive mercurial treatment should be started and continued for a month. The injection treatment with salicylate of mercury is best. If the disease has already advanced so that a positive Wassermann is present when it is first seen, and glandular enlargements are present, three full doses of salvarsan should be given at weekly intervals, and this followed by six weeks of intensive treatment with mercury. The reaction may be expected to disappear after two or three injections.

In florid syphilis, an intravenous dose of salvarsan should be given every week or ten days for from four to six doses. Then the salicylate of mercury injections or other mercurial treatment should be begun. After a course of mercury, treatment should be discontinued for six or eight weeks and a blood test made. If negative these tests are made every four weeks at at first, until a positive result is obtained, or until the tests continue negative. When a positive test is found, the salvarsan and mercury sequence is repeated.

Another method consists in giving the salicylate of mercury intramuscular injections five or six days after each salvarsan infusion. After the last salvarsan treatment, at least twenty injections of mercury should be given once every week.

In latent and tertiary syphilis, several courses of treatment are necessary before a permanent negative Wassermann reaction is secured. In some of these cases, despite repeated treatments, a negative reaction is never secured, although no active lesions of the disease appear.

If lesions refuse to heal under salvarsan and mercury it may be assumed that they are not syphilitic.

Neosalvarsan was introduced by Ehrlich with the hope that it would supersede salvarsan. It is a neutral solution, is less irritating, and the technic for its use is simpler. No alkali need be added. The water need not be hot. It is given in 0.45 to 0.9-Gm. doses. Usually 0.45 Gm. is given as the first dose, and 0.9 Gm. at the last three treatments. While salvarsan is administered in 150 or 300 c.c. of water, neosalvarsan may be given in 10 to 50 c.c. Neosalvarsan seems to be just as effective as salvarsan. Some observers find it more effective. Like salvarsan it must be followed by treatment with mercury. At least six injections are required, and often eight or ten before a negative blood reaction can be secured.

Intraspinal treatment has been used in parasyphilitic *locomotor ataxia* and *general paresis*. In these conditions intravenous injections of salvarsan alone seem not to be effective. The drug seems not to enter the cerebrospinal fluid. Salvarsan in the blood seems not to reach the germs lodged in the poorly vascularized tissues of the cord and meninges. Salvarsan in water can not be injected into the spinal canal because it is too irritating. For these cases the salvarsan may be used in serum. The patient is accordingly given an intravenous injection. An hour later, 50 c.c. of the patient's blood are drawn off and centrifuged. Of the supernatant serum, 12 c.c.

are removed and added to 18 c.c. of normal salt solution. If the serum is not perfectly free of cells it should be centrifuged a second time. This 30 c.c. of fluid is inactivated by heating at 56°C. (132.8°F.) for half an hour. It is then kept on ice until needed. A lumbar puncture is done, and 12 to 15 c.c. of cerebrospinal fluid drawn off, and the 30 c.c. of *salvarsanized serum*, raised to body temperature, is slowly injected. The patient is kept in bed for about twenty-four hours with the head lowered. This operation has most beneficial results. The Wassermann becomes negative, and after a few repetitions of the injections remains so in many cases. H. F. Swift and A. W. M. Ellis (New York Med. Jour., July 13, 1912) worked out this technic. If the injection is well tolerated, the dose may be raised to 40 c.c. of a 50 per cent. dilution after the first few doses. The number of injections must vary with the conditions, but eight or ten treatments, at intervals of two weeks, seems generally advisable. The results must be checked up by serum tests and the cell and protein contents of the spinal fluid.

H. S. Ogilvie (Jour. Am. Med. Assoc., Nov. 28, 1914) worked out a technic for the direct spinal administration of salvarsanized serum. He drew 50 c.c. of blood in a centrifuge bottle by means of a needle. This is centrifuged till clear serum is separated. To 15 c.c. of this serum the desired dose of salvarsan is added. This is done by mixing 0.1 Gm. of salvarsan with 40 c.c. of fresh distilled water. Each c.c. of this solution contains 2.5 mg. of the drug. This should be faintly alkalinized with sodium hydroxide. The temperature of the solution and of the serum should be the same when the two are mixed. The desired amount of the salvarsan solution is added to the serum to bring the dose up to not more than 1.0 mg. of salvarsan. This mixture is shaken up and placed in a thermostat at 37°C. (99°F.) for forty-five minutes. Then it is placed in a thermostat at 56°C. (132.8°F.) for thirty minutes. It is now ready to be used. Serum more than three hours old should not be employed. A lumbar puncture is done; 15 c.c. of spinal fluid is drawn; and the serum is injected slowly. The patient is kept recumbent for four or five hours with the foot of the bed elevated. Ogilvie advised that for repeated use 0.25 to 0.5 mg. of salvarsan is the most effectual dose.

Mercurialized serum, called *sublamin*, for spinal injection may be prepared as follows: 50 c.c. of blood are drawn from a vein in the patient's arm through a needle, and collected in a sterile flask. This is placed in the ice box for twelve hours, and then about 13 c.c. of clear serum is taken from it and centrifuged. About 10 c.c. of clear serum is obtained.

The mercuric solution is prepared by adding 1 Gm. of mercuric chloride to 1 liter of freshly distilled water. Of this solution, 1.3 c.c. contains 0.0012 Gm. ($\frac{1}{50}$ grain) of the mercuric chloride. This amount is added to the 10 c.c. of clear serum. Enough sterile normal salt solution is added to make a total of 30 c.c.

This mixture is then inactivated by subjecting it for an hour to a temperature of 58°C. (136°F.) It is then injected within an hour into the subarachnoid space of the cord. This is done with the patient on his side. About 10 c.c. of spinal fluid are allowed to flow out and then the solution is allowed to flow in by gravity.

C. M. Byrnes (Jour. Am. Med. Assoc., Dec. 19, 1914) mixed 1.3 to 2.6 mg. of mercuric chloride with 12 c.c. of human serum, adding 18 c.c. of normal saline solution, and inactivating at 56°C. (133°F.). This clear mixture can be injected into the subarachnoid space without irritation.

Neosalvarsan, being less irritating, is used directly for spinal injection. It may be used in salt solution without the intervention of blood-serum.

Intravenous injection may advantageously be given at the same time. L. M. Warfield (Jour. Am. Med. Assoc., Dec. 26, 1914) described the most effective method of administration. Nine-tenths Gram of neosalvarsan is dissolved in 18 c.c. of 0.5 per cent. sterile salt solution, made with freshly distilled water. One cubic centimeter of this solution contains 0.05 Gm. of the drug. One cubic centimeter of this is added to 9 c.c. of saline to make Solution 2. Four cubic centimeters of Solution 2 are added to 6 c.c. of saline to make Solution 3. Solution 3 contains 2 mg. of neosalvarsan to the cubic centimeter. These measurements are made with a sterile graduated cubic centimeter pipette and sterile glasses. With a 20-c.c. syringe, 17 c.c. of the first neosalvarsan solution is given intravenously. The patient is then turned on his side, and 1, 2 or 3 c.c. (preferably 2 c.c.) of Solution 3 is drawn into a 10-c.c. syringe. Spinal puncture is then made with an empty needle, and about 2 c.c. of cerebrospinal fluid allowed to escape. The syringe is then connected to the needle, and gentle suction made until the syringe is filled with fluid. Then the whole 10 c.c., the total contents of the syringe are very slowly, and with the least possible amount of pressure, injected into the subarachnoid space. Should it be desired to inject more than 4 mg. of the drug the dilution may be made stronger. Six milligrams should be regarded as a maximum spinal dose.

How practical these intraspinal injections are in the treatment of syphilis of the nervous system is doubtful. Usually the successful treatment of syphilis of the nervous system calls for intensive treatment. This means intravenous injections of salvarsan in doses of 0.3 or 0.4 Gm. every three or four days. This must be continued until the patient has received ten or twenty injections—and in some cases thirty or fifty injections. This is impracticable with spinal medication. While intraspinal injections are useful, it is probable that more can be done with intravenous injections.

Intraventricular injections are employed in paresis. The medication is deposited closer to the seat of the most serious lesions which are in the brain than when intraspinal subdural injections are given. The lateral ventricle of the brain is not difficult to locate, and it tolerates well the injection of neosalvarsan or salvarsanized serum. The technic of the operation was worked out by G. M. Hammond and N. Sharpe (Jour. Am. Med. Assoc., Dec. 18, 1915). Under general anesthesia a small scalp flap is turned down on the right side a little in front of the bregma and 2.5 cm. from the sagittal sinus. A trephine opening 1.5 cm. in diameter is made and the dura incised. A slender cannula with a blunt point is inserted at a point where no cortical vessel will be wounded, and passed downward and slightly backward into the lateral ventricle (see Topography of Lateral Ventricles, and Puncture of Lateral Ventricle, Vol. II).

The head of the table is lowered, and 10 to 20 c.c. of ventricular fluid allowed to escape. The head of the table is then raised, and a funnel containing the medicated fluid is connected to the needle by a short rubber tube and the fluid allowed to flow in slowly by gravity. The cannula is then withdrawn, the scalp wound sutured, a dressing applied, and the patient put to bed. For the second and later injections, the scalp is simply injected with anesthetic solution and the needle passed through the scalp.

The amount of medication used should be less than is injected in the spine. Salvarsanized serum and neosalvarsanized serum are employed. About 0.6 mg. of neosalvarsan may be given. The amount of fluid injected should be about the same as the amount of ventricular fluid withdrawn. The fluid withdrawn should be preserved for laboratory examination.

Subdural intracranial injections are made under the dura after removing a

button of bone. They are carried out the same as intraspinal injections. A small button of bone is removed over some silent area of the brain, preferably the frontal region, and a needle passed obliquely through the dura to tap the subarachnoid space. Gentleness should be used. An amount of salvarsanized serum or neosalvarsanized serum equal to the amount of cerebrospinal fluid which escapes should be injected. This treatment is, perhaps, especially indicated in *syphilis of the optic nerve.* It may be of special value in syphilis of any of the cranial nerves. For paresis it is less valuable than intraventricular injections, but, probably, more useful than spinal injections.

In all injections into the meninges the cerebrospinal fluid should be examined. The number of cells to the cubic millimeter of fluid should be counted. The amount of globulin should be estimated, and the Wassermann test of the blood should be made. The intraspinal injections can be given only at intervals of two weeks because a cell count at a shorter interval is not of much value.

Salvarsan and *neosalvarsan by enteroclysis* is practised with success. The bowels are emptied and the patient comes to the operation "hungry, thirsty and empty." An adult is given an injection of morphin, a child is given a dose of paregoric by mouth. The patient lies on his right side. A No. 20 French catheter in adults is passed into the rectum, or if possible into the sigmoid. The catheter is connected to the apparatus for giving enteroclysis. For the adult the requisite dose of the drug is dissolved in 240 c.c. of salt solution. The flow should be regulated to about 60 drops per minute. Experience with this method shows that the results seem about as prompt as when the drugs are given by the vein. This method is especially adapted to use in children. The drug may be given in a single *enema* of 150 c.c. 0 salt solution. The patient should be kept in bed.

Salvarsan by mouth has been proved to be effective. The drug is given in capsules. Ordinary gelatin capsules may be used, but better are capsules which prevent absorption in the stomach. The effect of the drug is much slower than when given intravenously, and larger dosage is required. Usually about three weeks are required to cause the disappearance of a macular or papular eruption. To prevent oxidation of the drug in the capsule, sodium hydrosulphite is mixed with it. A small dose of bismuth subgallate prevents diarrhea. Intravenous salvarsan is eliminated rapidly, and the use of the drug by mouth in addition to intravenous administration guarantees a more constant dosage. In cases in which intravenous or intramuscular medication can not be given, the administration by mouth is imperative.

Oil injections of neosalvarsan are quite free from danger. They are used the same as mercurial salts when suspended in oil. The injections are made in the gluteal muscles. This method has much to recommend it (see Intramuscular Injections, page 286).

Intramuscular injection of salvarsan is now rarely used. It is painful, and the effect is less certain. When used this way 0.6 Gm. is mixed with 6 c.c. of warm distilled water; to this 3 c.c. of a 4 per cent. solution of sodium hydroxide are added, drop by drop, and shaken well, until the solution is nearly clear; then normal salt solutuon is added to make about 10 c.c.; and this is injected into a gluteal muscle.

Subcutaneous injection of salvarsan is even more objectionable than intramuscular injection, as there is more danger of necrosis.

Conclusions Concerning Salvarsan and Neosalvarsan.—These drugs are effective agents against syphilis when used in conjunction with mercurial treatment. When used without mercury they are rarely effective.

The injection of salvarsan or neosalvarsan 4 or 5 times rarely produces a negative blood reaction. As many as six injections, even when followed by mercury often fail to produce a negative reaction. Eight or ten injections must often be given.

Neosalvarsan is equally as effective as salvarsan; and it is less irritating, less liable to give unpleasant reactions, and less difficult to administer.

Sodium dimethylarsenate (sodium cacodylate), injected into the muscles in watery solution, in doses of 0.06 to 0.12 Gm. (1 to 2 grains) seems to have much the same effect on syphilis as salvarsan.

Arsenobenzol (prepared by American chemists), called also *arsphenamine*, is essentially the same as salvarsan. It is an acid powder which makes an acid solution in boiling water, and must be neutralized before being used. It is supplied in ampoules containing 0.4 Gm. (6 grains) each. The average dose is 0.4 Gm. It may be given in doses of from 0.1 to 0.6 Gm. The average dose of the drug is administered by the following technic:— Into a flask having a capacity of 250 c.c. is poured 50 c.c. of freshly redistilled water. The drug is poured in the flask onto the water, the stopper inserted, and the flask vigorously shaken until the powder is dissolved. This takes about two minutes. Every particle should have gone into solution. Then a 15 per cent. solution of sodium hydroxide is added drop by drop. As the soda enters into combination with the acid salt, a cloudiness appears, but after about 15 drops of the solution have been added the whole fluid becomes a perfectly clear yellow.

The fluid is then poured through a sterile funnel containing sterile cotton, and the filtered fluid diluted with freshly distilled and cooled water until the total measures 100 c.c. The warmth of the solution should now be found to be about body temperature, and it is ready for injection into a vein. The solution is injected into a vein the same as salvarsan. It is best allowed to flow in by gravity through a small needle. The treatment should be combined with mercurial treatment the same as salvarsan.

Hydrotherapy is of decided advantage in the treatment of syphilis. Elimination is the important thing. The free use of water internally and activity of the skin, secured by warm baths, are as valuable as medication. Turkish or Russian baths once or twice a week should be taken if possible. Hot-water baths are of much value. Diaphoresis, secured by drinking copiously of hot water while in the hot bath, is useful. Mineral waters which can be taken more freely than plain water are of service. A cold shower or rub should follow the hot bath if possible. These methods stimulate the skin and improve its nutrition and thus render skin lesions less liable; the products of the disease are eliminated more actively; mercury is carried out of the system; and the bathing and stimulating of the skin, especially when followed by a cold shower, have a general tonic and invigorating effect, and render the patient less liable to take colds.

Conclusions.—Salvarsan acts on the organism much more rapidly than mercury. This is demonstrated in cases which have lesions which refuse to heal under mercury, and which are seen to clear up promptly with salvarsan. Cases of mucous patches clear up more rapidly under salvarsan. Malignant syphilis with severe cachexia yields surprisingly to salvarsan. Salvarsan may abort syphilis in its early stage before enough organisms have entered the body to give a positive Wassermann reaction. This is something mercury has probably never done. The action of salvarsan is rapid but not continuous; therefore repeated injections are necessary.

The idea that salvarsan in one injection could cure syphilis has long since been abandoned. In the primary stage of syphilis, especially before the

Wassermann reaction becomes positive, repeated injections of salvarsan may abort the disease. It is possible to cure syphilis with this drug within six months with two to four doses, but this is not to be expected with too great confidence in many cases. Serological tests should be found negative for at least a year after the first negative result is obtained.

Treatment begun during the secondary stage of syphilis with a positive Wassermann reaction requires much longer to eradicate the infection. Still it is possible with these cases by intensive treatment to effect a cure. Five or six injections of salvarsan at intervals of from one to four weeks should be followed by a vigorous course of mercury. It is possible to cure such cases in a year.

The later the treatment is begun the longer will be the period that is required to eradicate the disease. In old stubborn cases treatment begun during the tertiary period may require ten or twelve injections of salvarsan, with courses of mercury between each one.

About three-fifths of all syphilitics can count on securing an ultimate negative Wassermann reaction.

While the various therapeutic agents which are here described have the power of curing syphilis, *self-healing* of the disease occurs. An otherwise healthy person who leads a hygienic life may recover from syphilis without treatment. Such a recovery depends, perhaps, somewhat upon ancestral immunity acquired through syphilization.

The modern **intensive treatment** of syphilis now combines salvarsan and mercury. A good practice is to give four or five intravenous injections of salvarsan of 0.4 or 0.5 Gm. at intervals of five to seven days. At the same time, or immediately following the course of salvarsan, a course of mercurial intramuscular injections should be given. By alternating these two treatments the most intensive treatment is secured. If the case is seen early, before the Wassermann has become positive, one course of each drug may be given. If a strong reaction is present two courses of each drug may be given. The appearance of secondary lesions calls for three courses of each.

Mistakes in treatment, due to errors of diagnosis, are to be avoided. Syphilis is a very common disease. No one should be regarded as beyond its reach. Any doubtful lesion which does not respond to non-syphilitic treatment should be suspected. The modern methods of diagnosis make unjustifiable the common mistakes in treatment. In a single condition, the gastric crises of syphilis, a large number of patients are subjected to operations for other conditions. "Gastric ulcer," "appendicitis," and "gall-stones," are some of the diagnoses under which tabetics are operated upon. In many of these cases the first symptoms which the patients presented were symptoms of abdominal crises. After operation the symptoms continue, and these patients go from surgeon to surgeon, having their abdomens opened successively for one thing and another until a correct diagnosis is made or until they perish from misapplied therapy.

The **Wassermann test,** the **colloidal gold test,** or some similar test of the blood with biologic syphilitic products, whereby the presence of syphilis gives a characteristic reaction, should be used as the index of treatment. A positive reaction means that active spirochetes are present. A negative reaction in the early stage is not so reliable; but negative reaction after prolonged treatment, a positive reaction having previously been found, is very significant of cure. One patient may have positive findings changed into negative after forty treatments with mercury, another after fifteen treatments. It is not probable that mercury kills the spirochetes, but it seems to paralyze them. The fact that positive Wassermann reaction is

found sometimes in such diseases as leprosy, myxedema, scleroderma, lupus, tuberculosis, and valvular disease of the heart may mean that the cases are actually associated with syphilis. It may be assumed that negative reaction, in the absence of mercury or salvarsan treatment, is indicative of the absence of syphilis; and that repeated positive reaction indicates its presence. The Wassermann reaction requires special training for its application. It should be employed as a check upon all therapeutic attempts in syphilis. A negative Wassermann one year after the last salvarsan or mercury is the test of a cure. In tertiary and latent central disease giving locomotor ataxia and paresis the Wassermann from the blood is commonly negative; the subarachnoid fluid, however, gives a positive reaction and shows a large globulin content and many leukocytes.

The Wassermann can not be depended upon during the first week of the disease, but *spirocheta pallida* can usually be found in the sore; and if it is treatment should be begun at once.

From 10 to 15 per cent. of the active late manifestations of syphilis are associated with a negative Wassermann reaction. The surgeon must be guided by the symptoms and signs in these cases and disregard the reaction. This phenomenon probably occurs when the spirochetes are too few to give a reaction.

If, after salvarsan has been used, the serum reaction is repeatedly negative, mercurial treatment alone should be given.

The colloidal gold reaction is more sensitive than the Wassermann test, and seems destined to come into general use.

The Primary Stage.—In the primary stage of syphilis treatment is not employed unless the surgeon is sure of the infection. This must usually be determined by blood tests, by a knowledge of the positive entrance of infection into an inoculable wound, or by a positive recognition of the spirocheta pallida in the primary sore. In the event of any of these conditions excision of the sore is practised and active mercurial or salvarsan treatment is begun. This is the most hopeful time for treatment. Ordinarily the disease is not discovered until the sore, the primary eruption and lymphatic enlargements have appeared.

The *treatment of syphilis in the primary stage* is the great desideratum. Syphilis is most easily cured during that short period of a few days between the first signs of chancre and the appearance of the positive Wassermann reaction. This means that the first essential of treatment is early and positive diagnosis. This requires that the spirocheta pallida shall be discovered in connection with the chancre and that the early clinical signs of syphilis shall be present. To make this diagnosis positive in the presence of doubt a section of the chancre should be excised for examination.

The Secondary Stage.—It is during the secondary stage of the disease that treatment is pursued with the most vigor and the curative effect of mercury or salvarsan is invoked. This is held for practical purposes to be until the end of the second year, during which time the lesions tend to be symmetrical.

The Tertiary Stage.—The third stage of the disease, characterized by deep diseases, serpiginous sores, gummata in connective tissue, bone and muscle, nervous lesions and other non-symmetrical symptoms, is the stage for the introduction of the iodides if mercury and salvarsan have been used.

In giving the iodides in this stage the drug should be slowly begun and then continued until the lesion is cured or intolerance is reached. The question as to whether mercury or salvarsan shall be given with the iodin

or not must depend upon how thoroughly these drugs have been given. Usually the salvarsan and mercury should be continued just as is advised above, the iodide being regarded as a supplemental measure. Patients differ widely in their tolerance of iodin. Some can take 15 Gm. (200 or 300 grains) of the iodide of potash daily. Cases are reported in which as much as 60 Gm. (2 ounces) have been taken daily. Much depends upon the purity of the drug and the good health and eliminative power of the patient.

Hereditary Syphilis.—The treatment of hereditary syphilis should be considered under the following heads: (1) Prophylactic treatment of parents before conception, (2) treatment of the mother during pregnancy, (3) treatment of the child, and (4) general prophylaxis.

The *prophylactic treatment of the parents before conception* is the same as the general prophylaxis of the disease with especial care given to the sexual relations. Syphilitic persons who come into sexual contact with the non-syphilitic should receive the most vigorous mercurial or salvarsan treatment possible. It is the duty of the surgeon to warn against such contact until the disease is no longer contagious. When can the syphilitic marry? should receive the same answer as the question, When can the syphilitic cohabit? The earliest period at which the surgeon should consent that the syphilitic should marry is a year after treatment with mercury and salvarsan have been discontinued, and every sign of active syphilis has been absent, and repeated Wassermann reactions have been negative.

The *treatment of the mother during pregnancy*, if she had the disease before conception, if she conceived by a syphilitic man, or if she acquired the disease after conception, should be vigorous and according to the methods already given. If the treatment with mercury or salvarsan is pushed to the limit the woman will probably bear a living child, which may be either healthy or show syphilis in a mild form.

The *treatment of the child* if it is syphilitic should be started as soon as it is born and the disease is recognized. (Not all children born of syphilitic parents are syphilitic.) A small piece of mercurial ointment, equal to about ½ dram, is diluted with 3 times that amount of vaseline or zinc oxide ointment and rubbed on the skin under the binder. Once a day the skin should be washed with warm water and pure soap, thoroughly dried, and then treated with the mercury. A different place should be used each day. The same binder may be used for a week. In older children, or if inunctions cause dermatitis which does not yield to boracic acid solution and zinc stearate powder, medication by mouth must be given. A good formula is *Hydrarg. cum creta*, 0.005 to 0.03 Gm. (1/12 to ½ grain), given with 0.1 Gm. (1½ grains) of sugar 3 times daily after nursing. Some children do better on the red iodide of mercury with potassium iodide, in compound syrup of sarsaparilla and water. A child a month old may take 0.00015 Gm. (1/400 grain) of the red iodide of mercury and 0.05 Gm. (¾ grain) of the iodide of potassium thrice daily, increasing the dose every few days. In urgent cases the hypodermic method may be employed. A syphilitic child should never nurse from a non-syphilitic nurse. It should be remembered that iodin is eliminated largely by the milk and can be given to a nursing child by administering it to the nurse. The lesions in the infant are treated locally the same as in the adult. Cleanliness and good reaction of the skin are important. Ozena is treated by mild antiseptic irrigations. Ulcerations are cleansed and dusted with calomel or stearate of zinc. It is a matter of careful watchfulness in each case to find the amount of mercury which the child requires, and at the same time not to confuse the marasmus of syphilis with that of mercury.

In *hereditary syphilis* there seems to be danger in intravenous injections with salvarsan in the pregnant mother; but brilliant results have been secured by treating the syphilitic babe after it has come into the world. To get the benefit of salvarsan in these cases, the syphilitic mother should be given salvarsan about ten days after confinement, and the syphilitic child should nurse from the mother. The child begins to improve in a few days. Ehrlich believed this improvement is due, not so much to the trace of arsenic, but to the presence of endotoxins in the milk, liberated in the mother by the death of the spirochetes. If the mother has no milk or is not syphilitic then the child may nurse from a syphilitic wet nurse who has recently been injected with salvarsan. In the absence of such nursing, the blood-serum of the salvarsanized syphilitic mother, or of another person, should be injected into the child.

Local Treatment of Syphilitic Lesions.—The first consideration in the local treatment of syphilitic lesions is cleanliness and the protection of others from infection. These lesions are inflammatory in character and are amenable to the general treatment of inflammation. Artificial congestion is often of service. The lesions should be kept clean and dry. The best local treatment of *chancre*, if seen early, is aseptic excision, after the application of tincture of iodin. If the chancre is not excised it should be cleansed with warm water, dried and dusted with calomel powder. A simple gauze dressing may be applied. Rest of the part is essential. Cauterization of a chancre is usually not productive of good results. The patient should be warned of the danger of spreading his contagion. Caustics may be used in mixed sores which refuse to heal. Nitric acid or the actual cautery are best.

Sluggish ulcers, if not healed by calomel, may be dressed with the following ointment: Menthol, 0.3 Gm. (5 grains); iodoform, 15 Gm. (4 drams); wool-fat, 30 Gm. (1 ounce). If there is pain, cocain 1.25 Gm. (20 grains) to the 30 Gm. (1 ounce) may be added. Yellow mercuric sulphate powder is often of service. *Mucous patches* may be prevented by constitutional treatment and local cleanliness. When they appear they should first be treated by mild applications such as calomel, salicylic acid and iodoform. If they refuse to heal they should be touched with 10 per cent. silver nitrate solution, and this followed by antiseptic washes. Tincture of iodin is also effective. When mucous patches become indurated and form condylomata, an application of 4 per cent. corrosive sublimate in collodion (1.25 Gm. in 30 Gm. = 20 grains to the ounce) will remove them. When they become sluggish and do not yield to the above measures, acid nitrate of mercury (60 per cent. solution) may be carefully applied.

The *dry skin lesions* such as squamous patches and tubercles, may be cured by inunctions with 4 per cent. ammoniated mercury (1.25 Gm. in 30 Gm. = 20 grains to the ounce). Sometimes corrosive sublimate, 0.3 to 0.6 Gm. (5 to 10 grains), in 30 Gm. (1 ounce) of collodion or compound tincture of benzoin, is of service. When ulcers become phadenic, pure bromin, the actual cautery, or acid nitrate of mercury solution may be used. *Gummatous ulcerations* in the nose and mouth are best treated with applications of corrosive sublimate 0.06 Gm. (1 grain) in compound tincture of benzoin 30 Gm. (1 ounce). *Syphilitic vegetations* are treated with the calomel powder; but if intractable to calomel they usually yield to applications of chromic acid (50 per cent.), pure phenol or tincture of iodin.

Opalescent patches are treated with 10 per cent. chromic acid or curettement. *Herpes progenitalis* is treated with oleate of zinc.

Syphilitic iritis demands vigorous treatment. Constitutional mercurialization or salvarsanization should be pushed as fast as possible. The sur-

geon should have the coöperation of an ophthalmologist. The pupil should be dilated with atropin. A solution of 0.06 Gm. (1 grain) to the 4 c.c. (1 dram) should be dropped into the eye every two hours until dilatation is complete.

Syphilitic alopecia is treated by close cutting the hair and rubbing the scalp twice daily with the following: *Hydrarg. chlor. corrosiv.*, 1.25 Gm. (20 grains); *Tinc. cantharides*, 15 c.c. (4 drams); *Tinc. capsici*, 15 c.c., (4 drams); *Glycerin*, 30 c.c. (1 ounce); *Oleum ricini*, 30 c.c. (1 ounce); alcohol, 30 c.c. (1 ounce); and *aqua rosæ*, enough to make 240 c.c. (8 ounces). Ammoniated, mercurial ointment is also of service. Often a simple wash of weak bichloride of mercury solution (1:5000) gives as good results as anything.

YAWS (FRAMBESIA TROPICA)

This disease is due to the Treponema pertenue, a spirillum similar to that which causes syphilis, and its treatment is the same as that of syphilis. Salvarsan is most effective.

FISTULAS AND SINUSES, ULCERATION AND GANGRENE

FISTULAS

Fistulas are narrow abnormal openings, leading into hollow structures. Special fistulas will be found discussed under the special organs in which they occur. Fistulas are usually kept from closing by the discharges which originate in the organ and flow out through the fistula. There are several methods for accomplishing their cure. (1) The discharge originating in the cavity may be diminished or checked by appropriate treatment, usually best accomplished by antiseptic astringents. (2) The discharge may be diverted through some other channel or a new passage for drainage made. (3) The cavity from which the fistula springs may be obliterated by dissecting it out, by cauterization, by curettage, by causing its walls to collapse and adhere, or by the use of sterilizing caustics. (4) The fistula may have its lumen obliterated by pressure. (5) It may be healed by the injection of astringent antiseptics. (6) Its lining membrane may be destroyed and its walls caused to grow together by cauterization, by curettage, or by sterilizing caustics. (7) It may be dissected out *in toto*. (8) Discharge may be discouraged from coming through it, if there is another vent, by pressure at the mouth of the fistula. (9) The fistula may be laid open, its lining destroyed, and the whole made a part of a granulating wound. (10) Foreign bodies which contribute to keep up the discharge should be removed. (11) Rest of the part is often necessary to effect a cure. (12) Suction hyperemia is often effective if the fistula has not a mucous lining.

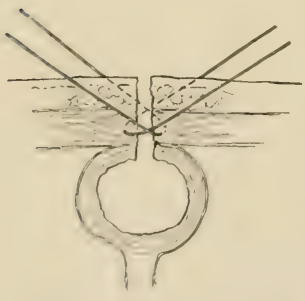


FIG. 178.—OCCLUSION TREATMENT OF FISTULA WITH SILVER WIRE.

The occlusion treatment of fistulas, such as lead into the stomach or intestines following gastrostomy, enterostomy, or ulceration, may be carried out by passing two loops of silver wire about the fistula, one on either side, introduced in such a way that they make pressure on the tract and emerge through the skin some distance from the mouth of the fistula (Fig. 178).

In operating upon a fistula or sinus, particularly if it is to be dissected out, it is desirable that the surgeon shall be able to identify it as he proceeds with his dissection. This is facilitated by staining its lining by injecting it with 5 per cent. methylene-blue solution. Not more than 0.3 Gm. (5 grains) of the drug should be allowed to be absorbed. Another method of tracing these tracts is by injecting bismuth paste and making an *x*-ray picture or fluoroscopic examination. A simple straight tract can often be followed by inserting a probe and dissecting about it as a guide.

It is often possible to do an aseptic extirpation of a fistula or sinus. The interior is injected with phenol or tincture of iodin. The region about the mouth is made clean and an incision carried around it. The mouth is then sewed up and painted with iodin. The fistula is then dissected out, care being taken not to open it. If it communicates with a viscus the stump is ligated, cauterized and treated like the appendix.

SINUSES

A sinus is a narrow discharging canal, communicating with a diseased cavity or focus, which does not show a disposition to heal. It is amenable to all of the principles of treatment laid down for the cure of fistula. A superficial sinus is best cured by laying it open and curetting its lining. Tuberculous sinuses can be dissected out and the wound sutured. Sinuses persisting after operations or in connection with wounds often do so because of the presence of an unabsorbed suture or other foreign body at the

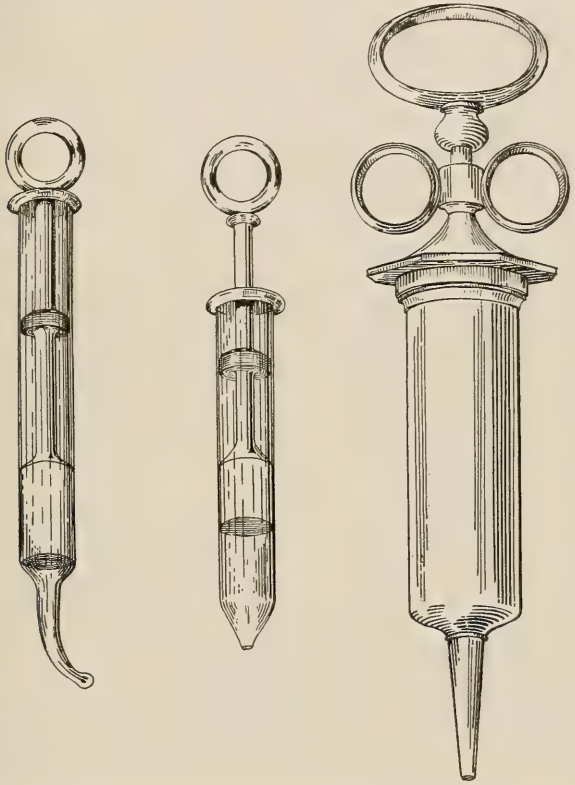


FIG. 179.—SYRINGES OF GLASS AND METAL FOR INJECTING PASTE.
The metal syringe may be connected to a small catheter.

bottom. Bullets, bits of cloth, rubber tubing, gauze, instruments, and dead bone have been found to be the cause of sinuses. The sinus heals when the foreign material is removed. A silk suture can often be fished out with a crochet hook.

The injection of sinuses with certain medicaments is the simplest method and often the most effective. Equal parts of alcohol and water is of value. Peroxide of hydrogen, followed by tincture of iodin or silver nitrate solution (2 to 4 per cent.), or phenol, followed by alcohol, are effective. In using strong antiseptics which are aimed to sterilize the whole sinus tract, the fluid should be passed down to the bottom and caused to reach every part. This can be done by inserting a fine rubber catheter or other hollow instrument to the depth of the sinus and injecting the fluid under some little pressure.

Sinuses not due to foreign body and not lined with mucous membrane are commonly cured by suction hyperemia. There is no treatment more simple and worthy of trial, and there is no condition in which this method of treatment gives more positive results.

The injection of sinuses with some substance which is solid enough to produce mechanical irritation and yet which in due time will be absorbed has proved of much value. This method is especially serviceable in tuberculous fistulas or fistulas not connected with a foreign body or necrotic focus to keep up the discharge. Iodoform suspended in olive oil or vaselin is of service.

Bismuth paste injections were introduced by Emil G. Beck, in 1906. He injected sinuses with a mixture of bismuth subnitrate, 33 parts, and vaselin, 67 parts. He employed this paste for diagnostic purposes, to locate the tract by the *x*-ray, but found that the simple injection cured the fistula and no operation was necessary. Two formulas are used. For diagnosis and for early treatment arsenic-free bismuth subnitrate (30.0 Gm.) and vaselin (70.0 Gm.) are mixed while boiling. For later treatment the following ingredients are mixed while boiling: bismuth subnitrate (30.0 Gm.), white wax (5.0 Gm.), soft paraffin (5.0 Gm.), and vaselin (60.0 Gm.). Bismuth poisoning has been so common that these strengths should be used only for small sinuses. For larger sinuses, the bismuth should constitute not more than 20 per cent. of the mass.

In some cases 1 per cent. of formalin may be added. Syringes of metal and glass (Fig. 179) are used. They should be sterilized by the dry process. The sinus is dried out with gauze strips as much as possible. The surrounding skin should be cleansed with alcohol or iodin solution. The paste is sterilized by heat and then cooled sufficiently not to burn the tissues and yet to remain in a liquid state. Sterilized paste which has cooled should be liquefied in a water bath before being used. It should be injected slowly with the syringe pressed into the mouth of the sinus until the patient complains of pressure. Every crevice should be filled at one injection or suppuration will recur. A sponge is pressed firmly against the mouth of the sinus to prevent the escape of the medicament until it has hardened. Hardening may be hastened by applying an ice-bag. One or more injections are required.

This method has proved of service in many varieties of sinuses, such as, following *psoas abscess*, *empyema*, *tuberculous joints*, *bone tuberculosis*, *chronic osteomyelitis*, *after resection of tuberculous kidney*, *rectal fistula*, *fecal fistula and abdominal fistulas*. It should not be used in acute suppuration or in the presence of cellulitis. It should not be used in large pus sacs as there is danger of bismuth poisoning.

The injected medication must reach the focus of necrosis or infection in order to be effective. If it does not, discharge will continue and the injection will fail. Failure may be expected if there is much necrosis or if a sequestrum is present. A foreign body such as a rubber tube, piece of gauze, or large amount of silk ligature will keep the discharge going. One injection will cure if it reaches the focus of the disease. Usually at least a week should elapse if the focus has not been reached by the first injection. If microscopic examination of the discharge from a sinus shows that there are no bacteria present, injection is not necessary as healing will take place without it.

Injections may be made for *prophylactic* purposes. This consists in opening a cold abscess and injecting 10 per cent. bismuth paste. The opening is best made with a knife. No drain should be used. Not more

than 90 Gm. (3 ounces) of injection should be used because of the danger of rapid absorption. The injection seems to prevent secondary infection. Beck has been able to prevent secondary infection in all cases thus treated. An incision is preferred to puncture because it permits evacuation of débris which does not pass through a trocar or needle. The thick paste seems to allow the escape of discharge but does not allow entrance of infection. For the prevention of bismuth poisoning the cavity should not be too tensely injected, large quantities should not be used. When large quantities are required they should be retained not longer than a week or ten days. The cavity should be washed out with warm olive oil upon the first appearance of

FIG. 180.—SINUSES IN CASE OF TUBERCULOUS SPONDYLITIS, INJECTED WITH BISMUTH PASTE; CURED.

poisoning. The oil is injected and retained for eighteen or twenty-four hours to mix with the paste. It should be withdrawn by suction.

It is well to precede the injection by radiographs to be sure that foreign body or sequestrum is not present. A radiograph after the injection shows its extent and should be taken for diagnostic purposes (Fig. 180).

This treatment not only proves effective in sinuses following tuberculous disease of bones and joints, but also in fistulas connected with the intestine and urinary organs. The value of this treatment in the most troublesome forms of fecal and urinary fistulas is well established. In *fecal fistula* the paste should be of thick consistence so that it will not run into the bowel. This may be secured by heating it but little. If mucous membrane completely lines the fistula bismuth paste will not cure it. The tortuous fistulas in which operation is difficult are most amenable to this treatment. As most fecal fistulas close spontaneously at least three weeks may be allowed

for the closure before bismuth paste is used. The paste should be injected every day or two. The injection should just fill the sinus, but should not overflow into the bowel in any large amount. The best results are secured if fecal matter does not occupy the fistula at the time of injection.

In *genito-urinary fistulas* the same principles are applied. Fistulas discharging urine, pus, or both yield remarkably to this treatment. Particularly in suppurating sinus which persists after nephrectomy are the results most gratifying. Practically all of these cases may be cured by this treatment.

Other substances are used with good results. As good results are obtained by some surgeons with paraffin, such as is used for prosthetic operations (see Vol. III). White wax, 1 part, and vaselin, 10 parts, mixed hot, and having from 0.06 to 0.3 Gm. (1 to 5 grains) of iodoform added to the mass injected, is effective. Iodin with iodide of potash may be used instead of iodoform.

J. R. Mitchell introduced *chalk paste*, made of equal parts of petrolatum and chalk, which is absolutely safe and seems to act quite the same as the bismuth. A salt of iron, such as the subcarbonate, may be used with paraffin. These substances serve also for skiagraphy.

Abrashanoff (Zentralb. für Chir., 1911, p. 186) cut a pedunculated flap of fascia from near-by tissue pushed it to the bottom of the sinus, and caught it with a few sutures. Contrary to what might be expected, it grows to the wall of the sinus.

Another method of value for treating sinuses is by the continuous bath. Immersing the part in water increases local hyperemia and leukocytosis. This applies not only to sinuses but to ulcers and wounds as well.

ULCERS

An ulcer is a solution of the continuity of the skin or mucous membrane which does not show the normal tendency to heal; and as such a surface must needs be infected, the two chief indications in the treatment are stimulation of the reparative processes and disinfection. Commonly there is some specific cause for the existence of the ulcer. This should be discovered if possible and removed. The constitutional treatment is important in persons having chronic ulcers, because the presence of such ulcers betrays a general defect in the vital resistance. Often ulcers fail to heal because of the restlessness of the parts; here immobilization is the chief therapeutic indication. In a large proportion of ulcers the disease is perpetuated because of deficient local blood supply; in such cases the remedy lies in improving the circulation. Disease of the nerve supply is also provocative of ulceration.

The removal of necrotic material from an ulcer is always an essential as such material acts as a culture medium for bacteria whose toxins depress the vitality of the living cells of the neighboring tissues. The disinfection of an ulcer is important for the same reason. The stimulation of granulations is the next matter of moment; after which should proceed the stimulation of epithelial cells to grow over the granulations. Exuberant granulations should be cut off or cauterized with silver nitrate.

In applying curative measures to ulcers the surgeon should first have an understanding of the cause of the disease and base his treatment upon a rational relation thereto. Few surgical lesions respond more satisfactorily to the application of correct principles. There are many means of treatment, all of which have their use in certain cases.

Dressings and applications should be used as in a wound. The question as to whether the dressing shall be stimulating or soothing must depend upon

the nature of the ulcer. Cotton should never be applied next to the sore. If an absorbent surface is desired gauze is the best. Ulcers with necrotic tissue should be treated by cutting away as much of the dead material as possible and applying a copious antiseptic wet dressing. Salves should not be used during the early stages when there is cellulitis and necrosis. Wet dressings, packs or continuous baths of boric acid, borax, sodium chloride, or sodium bicarbonate solution should be used in the inflammatory stage. If the discharges are foul, mercuric chloride solution (1 : 5000) is better. For stimulating granulation naphthalin and balsam-of-Peru are of value. Balsam of copaiba, tincture of myrrh (1 part, to 6 parts of water), tincture of iodin (1 part, to 10 parts of water), basic fuchsin ointment (1 to 5 per cent.), turpentine, 1 per cent. silver nitrate, castor oil, resorcin ointment, ichthyol ointment (10 to 25 per cent.), chlorazene ointment, chloramine ointment, spirits of camphor and iodoform are examples of other stimulating applications. Of all of these applications for uninflamed fresh ulcers, I prefer castor oil with 20 to 50 per cent. of balsam-of-Peru.

Bier's hyperemic treatment is often of service. Ulcers should be kept clean and the surrounding skin protected from the discharges. For stimulating small clean indolent ulcers tincture of iodin is valuable. Soothing and less stimulating applications are found in zinc ointment, boracic ointment stearate of zinc powder and phenol ointment. After an ulcer has become clean and granulations have sprung up, epithelial growth is hastened by dressings with mild antiseptic powders, such as subiodide of bismuth, subgallate of bismuth, stearate of zinc combined with either of the above, or some of the newer powders which liberate iodin, chlorin, or formaldehyde. Exposure to the rays of the sun proves effective in many cases (see Heliotherapy, Vol. III).

Excision of the ulcer is often the quickest expedient. This is especially true when the ulcer is old and lies upon much dense connective tissue which has developed as the result of the long-standing inflammation. The presence of this cicatricial tissue interferes with the blood supply and the ulcer is best healed by excising it and starting *de novo* with a clean wound. In performing this operation the ulcerated surface should have been dressed for several days with wet antiseptic compresses. On the day before operation the ulcer should have been dried and a compress wet with alcohol applied, provided the ulcer is not painful. Before operating the ulcer should be dried and painted with tincture of iodin, also the surrounding skin. An aseptic operation is then done, excising the ulcer by an incision carried around it and down to well-nourished tissue. The resulting wound may be treated as a granulating wound, or it may be wholly or partially closed by plastic operation by flaps from the same or from the other leg. If left open, skin grafts may be applied to the granulations at a subsequent operation (see Plastic Operations and Skin Grafting, Vol. III).

Curettage is of value in treating certain chronic ulcers which refuse to granulate or in which the granulations are flabby.

Pressure is a method which is efficacious in healing chronic indolent ulcers, particularly of the varicose type. The ulcer is rendered clean by moist antiseptic applications for a few days. It is then dried and completely filled with a copious application of a mild antiseptic astringent powder, such as subiodide of bismuth or subgallate of bismuth and stearate of zinc. A firm roll or pad of dry sterilized gauze or a hard bag of sawdust, just fitting the ulcer, is applied. The surrounding skin is copiously covered with the same powder, and over all are placed several layers of dry gauze smoothly spread out. The whole is held in place by a tight bandage of flannel or rubber

elastic. A similar bandage is also applied from the toes up, to prevent swelling. This dressing is left on for a week, and then renewed. The patient spends as much time as possible with the part elevated. At each dressing the skin is rubbed with alcohol.

Scarification is of value in stimulating clean indolent ulcers. The parts are prepared as for excision of the ulcer. The operation consists in making multiple incisions around the circumference 3 to 6 mm. ($\frac{1}{8}$ to $\frac{1}{4}$ inch) apart, crossing the margin at right angles and involving the outer part of the ulcer, and the skin (Fig. 181). This operation should not be done if there is already a dense bed of dense connective tissue underlying the ulcer.

Varicose ulcers are best treated by rest, cleanliness, elevation and the indicated measures described above. The initial treatment should be a hot wet antiseptic dressing. When it is necessary that the patient be about, treatment by pressure is of service. To support the skin and relieve superficial stasis a bandage is necessary or the varicose veins must be operated upon. No case is satisfactorily treated unless the veins are operated upon if varices are present.

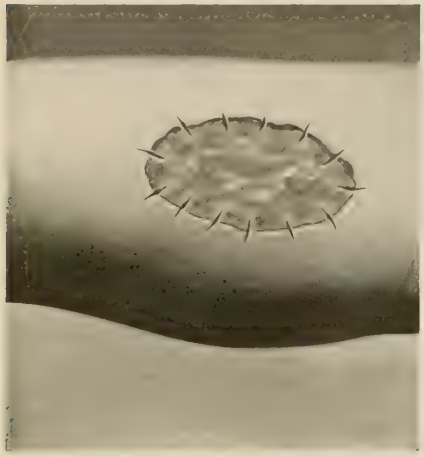


FIG. 181.—MARGINAL RADIATING INCISIONS IN TREATMENT OF CHRONIC ULCER.

The *zinc-gelatin* dressing of *Unna* is of value in these conditions, particularly if there is eczema of the skin. It is composed of zinc oxide and gelatin 10 parts each, glycerin and water 20 parts each, and ichthyol and boric acid 2.5 parts each. Another formula is 75 parts zinc oxide, 75 parts white gelatin, 250 parts boiling water, and 125 parts glycerin. The leg is scrubbed, shaved, cleaned with ether, thoroughly dried, and the gelatin preparation, softened by heat, is applied to the entire leg except at the site of the ulcer. The ulcer is treated with a simple dry powder dressing. A firm gauze bandage is applied evenly from the toes to the knee. No turns or reverses should be made. When it is desired to change the direction of the bandage, it should be cut. Another layer of the paste is painted over the first bandage and this covered by another bandage. Three or four layers are applied. A fenestrum is cut for dressing the ulcer. The skin dressing is renewed every three weeks at first, but later every four or five weeks. As the bandage easily becomes sticky it may be painted with shellac after it has become dry; or it may be covered with a dry bandage.

The exclusion of the air by means of an artificial scab is applicable in clean ulcers, and gives excellent results. This is accomplished by cleaning and drying the ulcer and surrounding skin, filling it with some bland absorbent powder such as subiodide of bismuth and zinc oxide, and then apply a tight strapping of diachylon or zinc oxide adhesive plaster. This is cut into strips 1.25 cm. ($\frac{1}{2}$ inch) wide and in length 3 or 4 times the diameter of the ulcer. The skin is dried, the strips are heated over the alcohol lamp and tightly applied, obliquely, in such a way as not to encircle the leg, and so as to make a decussating basket-covering over the ulcer and extending well beyond its margins (Fig. 182). A flat piece of gauze is laid over this; and a snug flannel bandage is then applied from the toes to the knee. This

dressing may be renewed every day or two at first, and later every three or four days.

P. G. Skillern, Jr. (Annals of Surg., Feb., 1916) worked out a treatment of varicose ulcers of the leg based on protection, drainage and support. Protection is secured by rubber tissue cut in strips about 1 cm. (⅓ inch) wide. These are placed at the edges to protect the new epithelium, but the middle of the ulcer is left uncovered for drainage. Or a piece of rubber tissue with a hole in the middle may be used on small ulcers. A smooth dry gauze dressing is applied to take up the discharge. If the patient can not rest in bed with the limb elevated, support must be applied to the tissues.

FIG. 182.—STRAPPING ULCER OF LEG.

This may be secured by a smoothly applied roller bandage; but is best attained by strapping with adhesive strips. Before applying the dressing and straps the ulcer may be filled with calomel powder. The paste of Unna is a valuable adjunct to this treatment.

Martin popularized a treatment by means of a rubber elastic bandage, 3 meters (10½ feet) long and 8 cm. (3 inches) wide, which is applied from the toes to the knee, evenly and firmly, lying directly upon the skin and the ulcer. Just before retiring at night the bandage is removed washed in clean water and hung up to dry; the leg is washed and rubbed with alcohol; excoriated places are anointed; and the ulcer is cleansed and protected with a dry dressing. In the morning the ulcer is cleansed with hydrogen peroxide, dried, powdered with mild antiseptic, the leg dusted with borated talcum, the bandage applied, and the patient goes about his business. This also gives good results.

The *sand treatment* is applied not only to ulcers to open but wounds. Clean sand is sterilized by boiling in muslin bags in a 1 per cent. solution

of soda, and the bags of sand dried. When used, the ulcerated surface is covered with sand, the sand lying in immediate contact with the tissues. The dry sand acts by powerful capillarity, dries the wound and stimulates it to healing. The sand bath may be used for twelve hours daily.

The use of *heliotherapy* (Vol. III), by exposing the ulcer to the direct rays of the sun for thirty minutes daily, is very effective. The arc light with a powerful reflector has much the same effect.

The methods above described render the healing of varicose and eczematous ulcers of the legs not difficult. Progress in healing can almost invariably be secured. After the healing has been affected and the varicose veins treated, efforts should be directed to prevent the recurrence which is prone to take place. The best possible general health should be maintained. The patient should be warned against continuing to stand or walk when fatigued. The circulation and nourishment of the leg and the reaction of the skin should be improved by daily massage with olive oil and alcohol alternately. The resiliency of the blood-vessels and the tissues can be improved by cold bathing, followed by rubbing, if not of the whole body then of the affected leg. Any little scratch or abrasion of the healed parts should receive immediate aseptic treatment. Tobacco and alcoholic drinks should be interdicted. Recurrence of ulceration should be met at once by rest and elevation.

Most patients can be kept well by these means. But unhappily many are compelled to stand or work at the time when rest is necessary for the control of the disease. If this is combined with lack of cleanliness the ulceration progresses. Often the ulceration has existed so long that the scar tissue extends into the vessels and muscles, and the nourishment of the skin is so shut off that while healing is secured in one place the skin is melting away elsewhere, and the ulceration creeps from place to place. Under such conditions the ulcer becomes intractable and defies all treatment. Even excision is ineffectual because of the great depth to which the infiltration extends. In such cases, if the patient is a man and the constant treatment of the disease interferes with his usefulness, *amputation*, generally at the knee, may be done. He then may have an artificial leg which on the whole is better than the diseased member, and his occupation need not be interrupted by treatment of the ulcer. Amputation is especially indicated in old ulcers involving the whole circumference of the leg. Amputation is indicated also in persistent chronic ulcers which because of their infection are throwing toxins into the circulation and causing damage to the kidneys and other organs. *Albuminuria*, appearing as the result of ulcer of the leg, which defies treatment calls for amputation.

Inflamed ulcers should receive, in addition to the treatment of the ulcer itself, the treatment which has been laid down for inflammation or cellulitis. A copious hot wet dressing of antiseptic solution, covered with impervious protective to retard evaporation, gives the best results.

Indolent ulcers have been considered above. They demand stimulating dressings.

Painful ulcers are often very trying. In addition to the ordinary treatment of the ulcer, they require relief of the pain which is usually due to the exposure of a nerve in the bed of the ulcer or to the compression of a nerve by the contracting scar tissue. Swabbing the ulcer with 95 per cent. phenol, followed in about two minutes with alcohol, every three or four days, is effective. The painful spot can often be identified with the probe, the nerve cocainized, and divided with a knife or destroyed with silver nitrate. If this is not done cocain locally applied is of value. It may be used in powder or in some bland ointment in 2 to 4 per cent. strength. In some

cases the simple covering of the ulcer with zinc oxide ointment relieves the pain. Gradually the nerve becomes covered and adapts itself to the conditions present. If the pain is severe and intractable excision of the ulcer should be done. **Irritable ulcers** and **neuralgic ulcers** are amenable to the same treatment as is applied to painful ulcers excepting that constitutional causes must be looked for and corrected. They often have to do with internal toxemias and the neurotic state.

Phagedenic ulcers break down and progress. This name should not be given to epithelioma. The peculiarity of the disease depends upon meager vitality of the tissues or upon virulence of infection or both. Antiseptic treatment and local stimulation of nutrition are called for. If these measures do not stop the spread of the disease some specific disease should be suspected and looked for. Syphilis, tuberculosis, leprosy, glanders and cancer produce such ulcers, and each is amenable to its appropriate treatment and is discussed elsewhere.

Pressure ulcers, often the result of improperly applied splints and other apparatus, are relieved by removing the pressure. Often a slough is present, and a surrounding area of cellulitis. This should be treated with wet antiseptic dressings until the slough has come away. **Indurated ulcers** are commonly old sores which are best treated by excision. If the induration is acute it is usually infective and requires the treatment laid down for cellulitis. **Trophic ulcers** are really atrophic ulcers, the most common example of which is the perforating ulcer of the foot which is discussed elsewhere (Vol. III). Parts in which the trophic nerve supply is disturbed are prone to ulceration. The ulcers are commonly sluggish and require stimulation, antiseptic applications and freedom from pressure.

Bed-sores are a form of pressure ulcers. When occurring in cases with paralysis of the spinal nerves they are trophic ulcers. Prevention is the important thing. Patients requiring to lie in one position upon the back for a long time, particularly if the subjects of depleting disease or paralysis of the nerves of the back, should have every attention given to the skin over the back of the pelvis. The sheets upon which the patient lies should be smooth and dry. The wet and wrinkled sheet is the prolific cause of bed-sores. No wrinkles or crumbs should be present to irritate the skin. Once or twice a day the patient should be turned on his side or lifted up and the back and rump rubbed with alcohol. If the patient is very lean the alcohol rub should be followed by rubbing with olive oil. The excess of oil should be wiped off and zinc oxide powder applied. A valuable *skin powder* for the back is, borax 1 part, lycopodium 2 parts, zinc stearate 3 parts. Should the skin over a bony prominence become red and angry or be abraded it should be protected by a ring to take the pressure off that part. The alcohol rub should be continued and before putting on the ring a large mass of zinc oxide ointment should be laid on the reddened place. Rings for protecting prominent places, threatened with pressure sores, are made by twisting gauze into a ring and covering and strengthening it by wrapping with gauze bandage (Fig. 93). This may be held in place with zinc oxide adhesive strips. Rubber rings of various sizes, to be inflated with air, are also made. If difficulty is experienced in protecting the bony prominences from pressure the patient should be placed upon a rubber mattress filled with water or air—the so-called *water bed* or *pneumatic bed.* The continuous bath treatment in a bath of warm water gives good results. Bed-sores should be guarded against not only back of the pelvis but also in very sick patients back of the scapulæ, heels, knees and elbows.

When a bed-sore has developed, the skin about it should be washed daily with soap and warm water, rubbed with alcohol and powdered. The sore should be dressed with a copious mass of zinc oxide ointment and protected from pressure by a ring. If possible the patient should lie in some position in which pressure is not made on the sore. If a slough forms it should be removed as soon as possible and a dressing of balsam-of-Peru applied. If stimulation of the sore is needed it is best secured with naphthalin powder and balsam-of-Peru. Overhanging edges should be packed under with gauze impregnated with these materials. Absolute relief of pressure is imperative. A bed-sore is a serious malady, and demands faithful and conscientious treatment. Unless it receives it, an extra, if not fatal, complication is added to the disease which keeps the patient prone.

Diabetic ulcers require, first, treatment of the constitutional disease, and second, treatment of the ulcer. Usually they are indolent and eroded by infection. Antiseptic applications and cleanliness are prerequisites. When the infection has been overcome stimulating applications are necessary.

It is also customary to speak of **acute ulcers** and **chronic ulcers,** all of which may be of any variety and which require antiseptic, soothing, stimulating, or some special treatment already laid down.

Bleeding ulcers bleed because of their relation to varicose veins which have ruptured, or because of the presence of an eroded artery, or because of exuberant and turgid granulations, or because of some constitutional hemorrhagic diathesis. If the bleeding is from a vein or artery some dry powder and pressure with a gauze pad will control it. If the bleeding recurs each time the ulcer is dressed the vessels should be caught with a needle and thread and tied. Bleeding from exuberant granulations should be met by cutting down the granulations or applying caustic. Constitutional conditions should receive special treatment.

Sloughing ulcers are treated by cutting away sloughs as fast as they form, and filling the cavity with naphthalin and balsam-of-Peru. If there is much bad odor, strong potassium permanganate solution applied as a wet dressing is effective. Powdered charcoal applied to the ulcer also has advantages. If the ulcer continues to slough and spread it should be cleaned, dried, touched with 10 per cent. solution of acid nitrate of mercury, and dressed with wet antiseptic gauze. This should be repeated daily until granulations begin to form.

Eczematous ulcers require the treatment given for varicose ulcers because usually they occur in the leg which is eczematous because of varicose veins or venous stasis. Ichthyol ointment (25 per cent.) applied to the skin around the ulcer is of value. The erosions which occur in eczema are treated with tar ointment (1 part) and zinc oxide ointment (8 parts).

Fungous or **exuberant ulcers** should be treated by cutting off the granulations, strapping, and antiseptic astringent powders.

Edematous ulcers require treatment of the edema and of the ulcer. Usually the edema is due to infection and should be treated by antiseptics such as wet boracic compresses. If it is chronic hyperemic edema it is best relieved by the pressure treatment and dry dressings.

Scorbutic ulcers, observed chiefly in old wounds in cases of scurvy, are treated by fruit juice internally and mild antiseptic dressings.

Oriental sore does not require radical treatment. Antiseptics, cleansing, and simple dressings heal it. Permanganate of potash is most effective. The cleansed sore should be filled with the dry powder. It may be covered with gauze or a collodion dressing. Healing should be secured in two or three weeks.

Malignant ulcers, namely ulcerating carcinoma or sarcoma, or carcinoma or sarcoma developing in a chronic ulcer, require complete and wide excision.

Rodent ulcer is a superficial epithelioma requiring excision.

Marjolin's ulcer is an epithelioma, and requires wide extirpation. These cancerous ulcers should be thought of and treated as cancer not as ulcers.

Tanner's ulcer ("chrome holes"), observed on the hands and nasal septum of workers in chromic acid, is prevented by keeping the hands and arms free from chromic acid. A protective ointment may be applied to the arms and hands. It is made of 3 parts petrolatum and 1 part lanolin. This is rubbed into the skin of the worker's hands and arms after washing and drying. It prevents absorption of the chromic acid and should be applied at least twice daily. The ulcers are treated the same as other ulcers.

For **Syphilitic Ulcers,** see page 302. For **Tuberculous Ulcers,** see Tuberculosis of Skin, page 837, and Tuberculosis, page 276. Ulcers of special diseases, regions and viscera are discussed in their appropriate places.

GANGRENE

Inasmuch as gangrene is due to inadequate blood supply to a part, the prophylaxis consists in preventing and overcoming those conditions which produce this effect. All gangrene is preceded by the premonitory evidences of deficient circulation. Watchfulness for these signs will often enable the surgeon to anticipate the disease and apply just the help to the enfeebled circulation that is necessary to save the tissues from death. The differences in local blood supply which mean death on one side or life on the other side are very slight, and the balance often is easily turned one way or the other. If a feeble heart fails to force the blood through the vessels of the extremities, the coldness and stasis are evident before gangrene appears. It is at this time that measures for quickening the circulation should be applied. Internal treatment to strengthen the heart, warm covering and applications to the extremities, and massage and rubbing will prevent gangrene in many instances.

The use of **hot air** is very effective. A current of air, heated to 200°C. (382°F.), is used on the gangrenous parts, and 80° to 100°C. (176° to 212°F.) on the surrounding sound parts. Daily treatments of thirty to forty-five minutes are given. By raising and lowering the limb, thus alternately, causing emptying and filling of the vessels, good results are secured in some cases. This has much the same effect as alternating warm and cold applications made daily, which in threatened gangrene after frost bite are especially effective. These treatments must often be continued for several weeks. In moist gangrene it rapidly causes drying.

Gangrene due to pressure is avoided by watchfulness. Infections near veins and arteries or in limbs already having deranged circulation must be guarded against and given energetic treatment when present. Thrombosis and embolism, the most common causes of gangrene, are discussed under their respective heads. They are both amenable to prevention and treatment. Arteriovenous anastomosis and the removal of thrombi and emboli from blood-vessels are often of value in preventing gangrene. When the main artery supplying a limb has to be tied, it is, perhaps, best to tie the vein also, as by this means the vessels seem to be kept distended and the danger of gangrene is lessened.

The **suction treatment** of gangrene is especially applicable to smaller members, such as fingers but it may be used in any extremity. The threatened extremity is placed in a suction vacuum apparatus, such as is used for inducing hyperemia. The upper limit of the apparatus, or the cuff, should

embrace sound tissue. Suction is then applied. A negative pressure equal to 12 to 15 c.c. of mercury is used. In the case of a small part, an incision may be made at the extremity, and as the suction is applied blood is drawn through the damaged part. Suction is applied for ten minutes 3 times daily, the wound being kept open by packing.

Gangrene due to **obliterating angeitis** requires for its prevention correction of unhygienic habits. Tobacco should be given up. Foci of infection should be cured. Heat from incandescent lamps seems useful in some cases. To remedy the viscosity of the blood by hypodermoclysis with normal saline solution is most important. Injections of 400 or 500 c.c. of Ringer's solution made with distilled water, in the connective tissue of the infraclavicular space, the submammary regions, and the thighs may be made daily or every second or third day. A series of locations for the injections should be used. If there is pain it is controlled by a warm compress. After ten or twenty injections the pain in the limb ceases in the cases of threatening gangrene. If gangrene is present, it becomes localized under this treatment, and pain stops.

Intravenous injections of a 2 per cent. solution of *sodium citrate* in distilled water once a week seem to have a beneficial effect in reducing the viscosity of the blood. Transfusion of blood from a duly tested donor has also proved beneficial. These methods should be tried if ten or twenty hypodermatic injections of Ringer's solution are not effective.

Experiments show that in some cases glandular extracts—thyroid, pituitary, thymus, ovary and testicle—have a beneficial effect.

Arteriovenous anastomosis may be reserved as a last expedient.

Rules for Amputation.—When an extremity has become gangrenous, as a rule it should be kept dry and protected from abrasion until a line of demarcation has shown itself, and then amputated. Of course, only dead tissue should be removed or such as will become dead if it is not removed. Amputation is not called for in localized gangrene of the leg if the foot is alive, nor is amputation of the foot to be practised for gangrene of the heel when the toes have circulation. The tissue, which is destined to become gangrenous may be discovered by elevating the limb for a few minutes and then allowing it to descend to the horizontal position. A line of demarcation will be noted as the blood flows back into the capillaries of the skin.

The site of amputation must be governed by the condition of the tissues above the disease. Gangrene due to feeble circulation in the legs requires the highest possible amputation that can be done without destroying the life of the patient: it is rarely wise, if the gangrene involves the whole foot, to amputate lower than at the knee-joint. In moist gangrene, due to venous occlusion, amputation may be done just above the disease. In gangrene, due to arterial occlusion, it should be done at the lowest point at which arterial pulsation can be discovered. In ischemic gangrene due to pressure the amputation may be done just above the disease. A general idea of the nutrition of the parts above the disease can be secured by examination, and whatever the cause of the disease amputation should not be done through tissues with such poor circulation that gangrene of the flaps will occur. The exception to this rule is that a low amputation in poorly nourished tissue is justified when septic absorption from the dead member makes amputation imperative and high amputation in well-nourished tissue would cost the patient his life. A trimming off of sloughing flaps may be made necessary by this course, or a later reamputation. Amputations for gangrene should be conducted with the greatest possible consideration for asepsis and for the conserving of the vitality of the patient. The use of the compression bandage

should be dispensed with if possible as it adds traumatism and impairs circulation. Amputation flaps are best not to be sutured.

Dry Gangrene (Arterial Occlusive or Senile Gangrene).—If the gangrene involves but a small part, as a toe, or if the part can be kept dry and free from infection, amputation should be deferred until the patient is well recovered from the depression which caused the disease. In the ordinary dry gangrene involving a single toe, it is best to allow the part to become thoroughly dry by keeping it covered with boric acid powder and a few layers of gauze, and practically to amputate itself, so that it can eventually simply be picked off. If it is thus kept dry and free from infection and allowed to exfoliate, no traumatism into the surrounding tissue becomes necessary, and a danger of extending the gangrene is obviated. Dry gangrene may become moist by the entrance of infection. Burrowing pus in a gangrenous part or in the tissues above it demands high amputation.

No positive rule for the site of amputation in dry gangrene of the leg (arterial occlusive or senile) can be laid down. The amputation should be as high as the resistance of the patient will tolerate. It is best done above the knee if the patient can survive it. The next place of choice is at the knee-joint, provided an aseptic operation can be done, and next in preference is below the knee.

Moist Gangrene.—Venous obstruction, causing gangrene, is most prone to infection and demands careful aseptic treatment. The part threatened should be kept as clean as possible and enveloped in antiseptic dressings. When the gangrene occurs, blebs and a general succulent condition of the skin are apt to appear. This should be met by discontinuing wet applications, and the part should be kept well covered with sterilized zinc oxide powder and boric acid, and protected with sterile gauze. Low amputation should be done as soon as a line of demarcation shows itself about a limb or member. If the gangrene is not positive or seems only superficial amputation should be deferred. Often gangrene will show itself in the ends of the toes and there will be some mottling of the foot with here and there positive patches of gangrene. In such a condition, tentative measures should be applied. The surgeon will often be rewarded for his patience by loosing only a distal joint of one toe and having some superficial exfoliations which will leave granulating ulcers. Spots of skin becoming gangrenous, if there are swelling and moisture, should be treated by an incision at the edge of the gangrene and slipping under it a strip of gauze for drainage.

Traumatic gangrene, found as an immediate result of thrombosing injury to blood-vessels or laceration or compression, should be met by treatment of such wounds or contusions as may be present, relief of the causative factor if possible, and the general care of the gangrene as already described. If gangrene is due to facture or dislocation and bony pressure upon the blood-vessels, the pressure should be relieved with the hope of restoring the circulation and of preventing spread of the disease.

Inflammatory gangrene, caused by infective embolism in an infected wound, often combined with the pressure of inflammatory exudate, requires treatment of the infective condition first. Amputation should be done early if positive gangrene of a member appears near the wound. Free drainage is imperative. Gangrene of a toe following an infected wound of the leg does not demand immediate amputation, but if the gangrene involves the foot and extends up the leg, amputation should be done at once.

Fulminating infective gangrene occurs in connection with virulent infections, commonly streptococcic, in persons of poor resistance, and should be met by the treatment laid down for acute infections and sloughing wounds.

The question of amputation must be determined by the degree of septic absorption that is going on. If the patient's life is threatened by septicemia, and free drainage and incisions do not improve the condition, amputation should be done, if the limb is gangrenous, irrespective of line of demarcation.

Gangrenous cellulitis sometimes involves the region of the wound or it may be associated with gangrene of the toes and fingers. The treatment is the same as for inflammatory gangrene plus the treatment of a sloughing wound: cutting away sloughs, antiseptic applications or cauterants.

Hospital gangrene, or sloughing phagedena, occurs in infected wounds, and unless checked continues to spread until death from sepsis takes place. It is best treated by cutting away sloughs, placing rubber tubes in all crevices and pockets, and instilling antiseptic solution. A nourishing diet is indicated (see Treatment of Infected Wounds).

Raynaud's gangrene is an arterial occlusive gangrene, and the treatment is the same as described above and under dry gangrene.

Diabetic gangrene should receive the same local treatment as the ordinary arterial occlusive variety. If it involves a toe, the dry antiseptic treatment should be applied, and amputation done at the time of election, or self-amputation be permitted to take place if infection of the gangrenous member is prevented. If the gangrene spreads to the foot, amputation of the leg is indicated, and should be done at the highest possible point. Many surgeons always amputate above the knee. The amount of sugar in the urine should not influence the surgeon in deciding for or against operation. Sugar does not constitute the disease, but it does demand the strictest asepsis in making and treating wounds. The presence of acetone-bodies is of prognostic importance. The administration of alkalies internally seems to be of value in preventing diabetic coma, and for that reason sodium bicarbonate should be given in 4-Gm. (1-dram) doses until the urine becomes alkaline. Coma is also prevented by increasing elimination by giving much water and by the use of saline solution by rectum, intravenously and hypodermatically. Ether is preferable to chloroform as an anesthetic. The general treatment of the diabetes is important (see Operations on Diabetics, page 181).

Gangrene from ergot poisoning requires the same treatment as arterial occlusive gangrene. The ingestion of the poison should be stopped (usually traceable to bread made from rye infected with *Claviceps purpurea*). The elimination of the ergot should be hastened by purgation and diuresis. Hot applications locally should be made with the view of dilating the vessels and improving nutrition. When the gangrene has positively declared itself and no further gangrene is threatened dry antiseptic treatment should be applied and amputation near the line of demarcation done at an opportune time.

Gangrene from frost varies greatly in the amount of destruction of tissue. The mild forms of *frost-bite* require gentle friction of the skin with cold cloths and then with the naked hand and cold water to restore the circulation and prevent gangrene. It is a well-founded rule in frost-bite not to bring heat to the part too rapidly. The vessels are paralyzed and there is extravascular exudate, and if they are relaxed by heat too soon more exudate is added to what is already present and harm is done. The exudate should be massaged away and motion restored to the blood by cold rubbing. (Snow is used in cold countries.) This should be followed by dry rubbing; and then heat may gradually be added. Or first cold water may be used and then the water gradually made warmer. Active movements of the part should be practised by the patient at intervals during the day, alternating with elevation of the part. The application of large compresses wet with hot normal salt solution gives relief.

As gangrene is threatened the parts should be kept dry. The skin should be rendered sterile with turpentine and oil. Blisters which appear should be punctured and dried. Gauze should be kept between the toes and fingers. Later to prevent gangrene of hands or feet the extremities should be elevated and massaged, and then lowered.

Sometimes after treatment an undue sensitiveness or induration persists; this is called *chilblains* or *pernio*. As a chronic disease the induration is best treated by suction hyperemia, iodin ointment, or ichthyol. If the skin becomes broken balsam of Peru is of value. If there is congested swelling, an astringent application such as subacetate of lead, sulphate of copper (2 per cent.), alum, or compound resorcin ointment is of value. If the skin is tender and easily becomes abraded, collodion containing 10 per cent. of iodoform may be applied.

Extensive and deep frost-bite should receive the treatment described above. Until gangrene shows itself the tissues should not be despaired of, but, following the cold, heat and massage should be persisted in. The skin should not be broken. When gangrene appears the parts should be kept aseptic and dry. Amputation should be deferred. Often bad-looking tissue will simply suffer superficial necrosis, leaving an ulcer which can be healed. If the parts can be kept dry it is best to allow gangrenous parts or limbs to show a line of demarcation, and toes and fingers to suffer self-amputation with a little assistance. Amputation or the treatment of gangrenous patches should usually be simply the trimming away of dead tissue. If the gangrene becomes moist and infected, amputation of the dead part need not be delayed.

Trench-foot, the result of vasomotor disturbance, cold and inaction, is a gangrene which requires local treatment by warmth, asepsis and removal of dead tissue. The pain and unequable blood-pressure may be remedied by the internal administration of iodid of potassium.

Noma (gangrenous stomatitis) should be watched for in debilitated children suffering with acute diseases, especially measles. The mouth should be kept clean, the teeth should be brushed, and carious teeth attended to. Upon the first appearance of an ulcer of the mucous membrane, upon the inner side of the cheek, corner of the mouth or gums, it should be cauterized with the silver nitrate stick, pure phenol, or dried and touched with tincture of iodin. When gangrene has developed it is imperative that the diseased tissue be removed. The operation should be done thoroughly. The necrotic material should be cut away with blunt pointed scissors and the wound cauterized with the actual cautery down to sound tissue. If the disease is not checked it is fatal; and the resulting deformity of operation is easily remedied by plastic operation. In the place of the actual cautery pure phenol followed by alcohol may be used, or other chemical cauterants; but these are of service only in mild cases.

Phagedenic gangrene and **sloughing gangrene** are forms of hospital gangrene or destruction of tissue by infection in persons of meager resistance. The treatment is similar to that of sloughing wounds and phagedenic ulcers. It consists in improving the general nourishment and resistance, cutting away sloughs, and applying the cautery or chemical cauterants. Among the cauterants of most value are phenol, nitric acid, and chloride of zinc. The vigor of the treatment must depend upon the general sepsis, the patient's resistance, and the amount of cellulitis about the disease. Copious wet antiseptic dressings should be applied. The cauterants are indicated in phagedenic gangrene. In sloughing gangrene without a tendency to extend, simply cutting away the sloughs and applying antiseptic dressings suffice.

Phenol gangrene is a common result of the use of phenol solutions applied to the extremities. Solutions as weak as 1 or 2 per cent. have caused this disease. Phenol solutions should not be left on the fingers or toes for any considerable length of time. Solutions of other chemicals such as lysol, sodium hydrate, potassium hydrate, acids and "campho-phenique" are also capable of producing gangrene of extremities. Usually a 3 to 5 per cent. solution of phenol is responsible for the damage. When the gangrene occurs, alcohol should be applied. This should be followed by aseptic dryness secured by boric acid powder. A line of demarcation should be awaited. In due time the gangrenous tissue will separate, and often a little **trimming** is all that is required to complete the operation.

Trophic gangrene requires the treatment of dry gangrene due to arterial occlusion. **Ainhum** requires amputation at the site of constriction.

The so-called **presenile, spontaneous** or **nonsenile gangrene** is a dry gangrene requiring the appropriate treatment for that disease. The same may be said of those occlusive gangrenes designated as **embolic, postfebrile,** and those due to the poisons of *lead*, *mercury*, *tobacco*, *arsenic*, *syphilis*, *leprosy*, *gout* and *nephritis*. They are due commonly to arterial occlusion resulting from disease of the intima causing thrombosis *in situ* or to thrombosis swept from some other part; and their treatment is the same.

NUTRITIVE DISTURBANCES

SCURVY

Scurvy becomes a surgical disease because of the hemorrhages, gingivitis and necrosis of bone which require treatment. Prophylaxis is most important. Good hygiene prevents the disease. Simple nourishing food in proper variety and fresh air are the preventives. Diet should consist of proteid, carbohydrates, mineral salts, water and fresh vegetables or fruit. Lime juice alone will not atone for the absence of variety. The disease develops among people who live unhygienically and upon a monotonous dietary. Meat, bread and coffee compose the diet of many patients. Fresh fruit and vegetables are the most effective antiscorbutics.

When scurvy has developed the constitutional treatment consists in rest, fruit juices and a nourishing and varied diet. Cleanliness is essential. The diet should be increased particularly in the line of those things which the patient has not had. Hemorrhagic effusions are best treated by massage. The gingivitis should be treated by cleansing the teeth, and by the local use of astringent antiseptics. Mouth washes of permanganate of potash solution (5 per cent.), lemon juice, alum and silver nitrate (2 per cent.) are useful.

RICKETS

Rickets is a disease characterized by a deficiency of earthy salts in the bones, due to defective nourishment, in childhood, on account of which the bones become bent and deformed, and require surgical treatment for their correction. The disease should be prevented by proper food, which means a correct proportion of essential food elements in childhood. Human breast milk is necessary for the best health in infancy: there is no substitute. Rachitic children are those which have been fed upon artificial foods containing much starch or upon cow's milk modified by heat. Fresh air is also an important factor in prophylaxis. When the disease has developed the treatment consists in regulating the hygiene of the child. Proteid, carbohydrate, mineral salts, water and fresh vegetables should be represented in correct proportions. Phosphorus and cod-liver oil are of value. The general health of the child should be improved by daily baths and massage. Soft bones should be relieved of weight by recumbency and in older children by apparatus. As the child grows stronger and the bones begin to be nourished adequately braces should be applied to correct bow-legs, knock-knee, etc. (see Vol. III). Operations need not be done while the bones are soft; but in cases in which deformities have not been overcome by braces and the bones have become hard operation should be directed to the correction of the defects (see Operations on Bones).

ACROMEGALY

Acromegaly is amenable to surgical treatment only so far as hypertrophy of bone is concerned. The internal treatment should receive first consideration. General improvement of the personal hygiene is necessary. The use of thyroid extract seems to be of help in some cases. The dried powder of

thyroid glands is given in doses of 0.3 Gm. (5 grains) thrice daily. If it makes no impression on the disease after a fortnight or two it should be stopped. Hypertrophied parts may be subjected to plastic operation. I have in one case been able to contribute to the comfort of a patient by amputating the last phalanx of the hypertrophied great toes.

In the majority of cases of acromegaly there is hypertrophy of the hypophysis. For a further discussion of treatment see Hypophysis Cerebri, Vol. II.

GIANTISM

Giantism is probably due to hyperactivity of the pituitary body (hypophysis cerebri) during the growing period of youth. If discovered early, surgical attack upon the hypophysis may be made. Adventitious pituitary tissue in the vault of the pharynx may contribute to the hyperpituitarism. The regulation of growth has much to do with this gland. At the same time, the thyroid, adrenals, pancreas, testicles and ovaries, all are interdependent in their functions with the hypophysis; and the treatment of disturbances of growth must take into account all of these organs.

The treatment of this condition if recognized early is largely medical. Once established there is not much that can be done. It is inconvenient for a person to be much taller than the average. The most advantageous height in Anglo-Saxon countries is between 168 cm. (5 feet, 7 inches) and 178 cm. (5 feet, 11 inches). A person over 180 cm. (6 feet) tall may have pride in his height, just as a woman may have pride in hair that reaches to her feet, but as a rule these excesses are of more disadvantage than advantage. Moreover, they are usually signs of physical weakness rather than of strength. As the surgeon was once a barber and came to the relief of those who were suffering with excessive growth of hair, so now does he offer relief to the victim of excessive growth of long bones. It is possible to remove 5 or 7 cm. (2 or 3 inches) of bone from the middle of the thigh and 2.5 cm. (1 inch) from the middle of the tibia and fibula; also 3 or 4 cm. (1½ inches) from the humerus, and 2 cm. (¾ inch) from the radius and ulna. In performing such operations as this, the operation should not consist of simple transverse division of bone, but a mitered or wedge-shaped union of the bone should be made to insure retention and healing in correct position.

DWARFISM

Where dwarfism is due to premature ossification of epiphyseal cartilages, there is no effective treatment. Where it is due to inherent trophic disturbances, it may be hoped that glandular therapy will prove of avail. Stimulation of the epiphyseal growth of bone is possible by applying hyperemia to the upper end of the tibia and fibula and to the lower end of the femur before ossification has taken place. Rachitic dwarfism with deformed long bones is amenable to the straightening of the bones by osteotomy.

CRETINISM

Cretinism is susceptible to surgical treatment only as it is capable of being helped by the implantation of thyroid or other gland substance from a consanguineous donor, and as bone deformities may be helped by osteotomy. The most effective treatment thus far has been medical, and consists in the internal administration of dried and powdered thyroid gland obtained from such animals as the sheep.

TUMORS

General Principles of Treatment.—Clinically, tumors may be divided into benign and malignant but the differentiation is often difficult. Another matter of importance is the fact that tumors which were at first benign later may become malignant and before the surgeon can be aware become incurable. Another consideration of moment is that many tumors which answer to the microscopic requirements of benignity are really deadly because of their effect upon the general health through pressure, through interference with the functions of neighboring organs, through hemorrhages which they may produce, and through internal secretions which they throw into the blood. There are other tumors classified as benign which produce metastases and ultimately prove fatal. All of these conditions lead to the conclusion that the best treatment of all tumors is extirpation. There are certain exceptions to this rule, to be found in multiple tumors too numerous for removal, tumors which can not be removed without sacrificing the life of the patient, and small tumors which are plainly benign and yet which are easily accessible and eradicable should they become malignant. The safe side is the removal of these latter growths. A tumor is always a menace. A wise rule is to extirpate any tumor which is increasing in size if extirpation is practicable.

For the **extirpation of tumors** no special instruments are required. For drawing tumors from their beds while being freed by dissection, it is customary to grasp them with tenaculum forceps. In the case of certain very delicate tumors in deep places, such as tumors of the brain or tumors of the thoracic cavity, tenacula can not well be used, nor can the hand or a spatula be introduced behind the tumor. To meet such conditions, F. Krause (Mediz. Klinik, vol. vii, No. 2) devised a glass suction cup, whereby suction is used for the purpose of retraction (Fig. 738, Vol. II). By connecting the cup by a rubber tube with a hydraulic pump or with a vacuum bottle, and by having a hole in the cup which may be controlled by the operator's finger, the tumor may be drawn out with the minimum amount of traumatism.

Benign Connective-tissue and Special Tissue Tumors.—Benign connective-tissue tumors should as a rule be removed. Usually they possess a capsule from which they are easily shelled out. They are practically without nerve supply (excepting the neuromata), and can often be operated upon with local anesthesia. When closely incorporated in an organ often the organ from which they spring must also be removed.

If the tumor is subcutaneous and produces much swelling the skin will fall together more smoothly after its removal if an ellipse of skin is removed with the growth (Fig. 184). When the line of cleavage is found the tumor is easily shelled out. Good retraction of the skin or surrounding parts is a necessary help. The handle of the scalpel or the end of round-ended curved scissors to make blunt dissection, with an occasional stroke to divide resisting tissue, accomplishes most of the removal of benign encapsulated tumors. Usually the wound can be closed snugly with a subcuticular suture and primary healing is secured.

Lipoma but rarely undergoes malignant degeneration, and its removal is usually called for because of the objections to its physical presence. The fact that it is most commonly subcutaneous makes its removal under local analgesia easy. Some lipomata seem to break through thin capsules and are continuous with the natural fat of the neighborhood, in which event the surgeon can not be sure just where the tumor ends but there is never harm in excising fat no matter where it is situated.

Multiple lipomata are usually not removed unless they are troublesome. An irritated lipoma is best removed. In operating for lipoma the surgeon should be sure it is not an aneurism or the sac of a spina bifida that he is dealing with. *Lipomatosis* appearing in a thick layer under the skin, for esthetic purposes and for the comfort of the obese, may be removed with advantage if it has failed to yield to hygienic measures. A wedge-shaped piece or ellipse of fat may be removed from the abdomen, hips or from beneath the chin, and the wound closed.

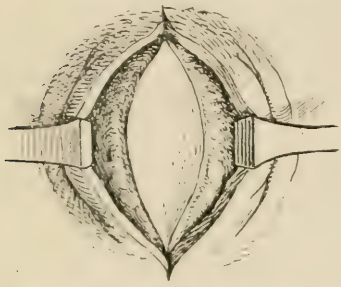


FIG. 184.—SHOWING METHOD OF REMOVING ELLIPSE OF SKIN WITH TUMOR TO FACILITATE SMOOTH CLOSURE OF WOUND.

Chondroma, being usually associated with bone and encapsulated, is easily removed. Usually incision of the capsule and shelling out of the tumor is required. When the tumor becomes large and lobulated more radical operation is required. Amputation may be necessary if it completely surrounds the bone.

Osteoma is removed when it interferes with the motions of joints, muscles or the blood, when it presses upon nerves or other important structures, when for cosmetic reasons its removal is desired, or when it continues to grow toward structures upon which pressure would be dangerous or painful. Osteoma is removed from the bone from which it springs by means of the chisel or forceps, after dividing and retracting the overlying soft parts.

Myeloma, the benign red-marrow tumor often mistaken for sarcoma, springing from the cancellous tissue of bone in persons under thirty, bursting through the shell of the bone, and characterized by its rich red vascular structure, with its numerous large multinuclear giant cells imbedded among spindle cells and round cells, is best treated by excision simply of that portion of the bone involved in the tumor. It is not necessary to go wide of the growth; if some part is not wholly removed by the excision thorough scraping with the curette and the application of some caustic will eradicate the disease. Many of these growths are cured with the curette alone. They require treatment usually in the head of the tibia, in the ends of the tibia, ulna, radius, humerus, femur, clavicle, body of the mandible, and alveolar processes. Many limbs were amputated before it was learned that these tumors could be cured by less radical means.

Myoma, *myxoma*, *endothelioma*, *neuroma*, *neurofibroma and fibroma* should be removed with as little damage to the surrounding structures as possible.

Benign Epithelial Tumors.—These tumors require the same treatment as benign connective-tissue tumors, with this exception: they are more prone to undergo malignant changes; hence their removal in persons past middle life is more urgently indicated.

Papilloma, when large, should be removed. The smaller papillomata of the skin (warts) are best treated by cauterization with nitric acid. Pap-

illomata of special regions, such as the ovary and bladder, are discussed elsewhere.

Adenoma should be removed whether in the young or old because of its strong inclination to become changed into carcinoma. It is discussed further with the organs in which it most commonly occurs.

Nevus and *angioma* if small may be excised. If larger it may be cured by electrolysis by inserting two needles and traversing the growth with a strong electric current; or it may be cured by injections of hot water. Liquid air and carbon dioxide have proved effective applications (see Skin Nevi, page 842; and Angioma, page 453).

A most satisfactory treatment of nevus is with radium. This combined with thermoradiation gives the best results. Flat capillary nevus exposed for five minutes to radium, cyanotic nevus for ten minutes, and elevated nevus for fifteen or twenty minutes undergo a striking change . A brownish pigmentation appears in about nine days. There are slight exudate and scab formation, local infiltration, and desquamation, lasting for several weeks. One area after another is treated until a cure is secured.

Injections of boiling water require care and skill. Too great heat near the skin may result in sloughing. The temperature of the water should be as near 100°C. (212°F.) as possible. The danger of embolism may be obviated by peripheral compression. A glass syringe with an asbestos piston serves best. By wearing thick cotton gloves the surgeon may handle the hot syringe. The angiomatous skin does not tolerate the hot needle well so the needle should be inserted through the healthy skin. The injections should be made into the tissues beneath the angioma rather than into the cavernous structure. Several punctures may be made about the periphery, injecting always under the tumor. The hot water should not cause much tension. When the skin begins to have a grayish tint the injection should stop, and be transferred to another area. If the tumor is larger than 6 or 8 cm. (2½ or 3 inches) in diameter, it is well to inject only a portion of it and repeat the operation two weeks later. Several treatments may be given. Several ounces of water may be used at each operation. Edema of the surrounding tissues lasts for a few days. The tumor shows hardening after the treatment. It can be seen to be cured in the course of two months. A soft area appearing after the injection should be treated by another injection.

Cystomata.—*Benign cysts* demand the same treatment as is given to benign solid tumors. Echinococcus cysts, infected cysts, and papillomatous cysts require immediate removal. Cystadenomata in persons past middle life should also be removed. Cystic sarcoma and cysts which have undergone carcinomatous degeneration are malignant tumors and should be treated accordingly. The benign cysts are best removed, but there is no urgency unless they interfere with the function of parts or organs or are otherwise a source of annoyance to the patient. It is desirable that they be removed, however, because their natural tendency is to become larger, and it is easier to remove a small cyst than a large one; if removed at once the patient is spared the disadvantage of carrying a tumor which eventually must come to operation; there is always a possibility of carcinomatous degeneration beginning in the epithelium with which cysts are lined; suppuration may develop in the interior of the cyst; and even though not causing gross interference with function the presence of a tumor exerts a secondary inhibitive action upon the normal physical and mental activities of the patient.

Small cysts are best dissected out unruptured. The same, of course, is

true of malignant and infected cysts. Larger benign cysts may often be removed best, and through smaller wounds, if their contents are drawn off after the cyst is exposed. This tapping is done with a trocar and canula to conduct the fluid away from the wound in case it may be infective.

Infected cysts require especial consideration. If there is any suspicion that the cyst is infected, before tapping, a stout silk suture should be applied on the cyst wall in the form of a purse-string ring, the trocar inserted in the middle of this circle, and the thread tightly tied as the trocar passes in, to prevent leakage (Fig. 185). In tapping suppurating cysts the wound about the place of tapping should be walled off with packing. The same care to prevent escape of the cyst contents and infection of the wound should be exercised in dealing with echinococcus cysts and with papillomatous cysts.

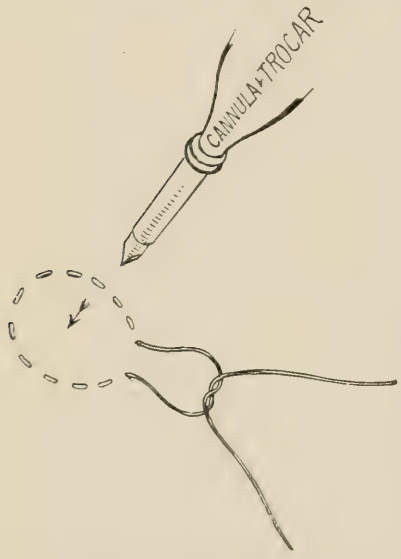


FIG. 185.—PURSE-STRING SUTURE IN WALL OF INFECTED CYST TO PREVENT LEAKAGE WHEN TROCAR IS INSERTED.

Small sebaceous cysts may be removed by making a crescentic incision in healthy tissue near the base of the cyst. Through this a hook, like an aneurism needle, is passed and the cyst isolated by blunt dissection. This may be done without bursting the cyst. When it has been freed it is popped out of the wound like a cataract.

It sometimes happens that a cyst, large or small, can not be dissected out completely, and some of its structure must be left behind. It should be remembered that most cysts are lined with epithelial cells which are responsible for the secretion that fills the tumor, and in order to prevent recurrence the epithelial lining must either be removed or destroyed. Leaving the smallest patch of epithelium will often result in a recurrence of the cyst if the overlying wound is tightly healed or in the formation of a persistent sinus if there is an opening for the escape of the epithelial discharge. If all of the cyst wall can not be removed, often the mucous membrane lining can be dissected out or curetted away. If this can not be done the epithelial cells should be destroyed by cauterization. For this purpose the actual cautery is best, but in lieu of that some chemical caustic such as acid nitrate of mercury, chloride of zinc, or nitric acid should be used. The vitality of these cells is low, and often such simple measures as the application of phenol, tincture of iodin, or silver nitrate causes their destruction. Wounds treated by caustic should be drained. Cyst walls which have undergone calcareous degeneration should have all calcareous material removed, otherwise persistent sinuses may result. If for some reason a cyst can not be dissected out, it may be treated by free incision, treating the inside with phenol followed by alcohol or painting it with some chemical cauterant, and packing it with gauze. This treatment applied a few times will result in destruction of its epithelial lining and adhesion of its surfaces.

Echinococcus cysts should be removed unruptured if possible, as rupture scatters the brood-capsules, and dissemination of the disease may occur. The wall of the cyst should always be removed when a cyst has to be opened.

In treating this disease in the liver and lungs, the mother cyst is often found infected with bacteria of suppuration and the enucleation of the mother cyst unruptured is impossible. In such event the cyst should be opened, evacuated, and then the cyst-wall removed by blunt dissection and peeling it out of its cavity. The prophylaxis of this disease consists in abstaining from the society of dogs; the society of human beings is better, and people need one another more than they need dogs.

Teratomata should be removed *in toto*. If any part of the tumor is left it is prone to continue growing and in later life to develop into malignant disease.

Malignant Tumors.—The prophylaxis of malignant tumors consists in good hygiene. We do not know the cause of the disease. If they are infectious then it would be wise to avoid living in houses which had been occupied by patients with such disease. There is reason to suspect the infectious character of cancer and that there are such things as "cancer houses" or domiciles in which occupants are particularly prone to develop the disease. This is proved to be the case with the cancer of mice and rats. It is well known that the disease is on the increase among so-called "civilized communities:" *i.e.*, communities in which there are the greatest violations of hygiene, or in which the greatest deviations from simple natural life exist. The closer people live to the conditions of natural society, inspired by mutual aid, the less cancer is found; the more complicated life becomes, with the anxieties and jealousies of competition, the egoism of personal acquisitiveness, the contest for gain, the modern urge to become parasitic and to be supported by the labors of others, and the stress and struggle to secure livelihood without performing useful service, the more cancer is found. Cancer also has as an etiological factor the other physical conditions which provoke senility, such as: the use of alcohol, tobacco, tea and coffee; syphilis, hereditary and acquired; fermentation and putrefaction of intestinal contents; infective foci; excessive meat diet with insufficient muscular exercise; insufficient fresh air; and overheating in winter, producing greater susceptibility to disease and lowering of bodily resistance. To prevent cancer, one must keep young and delay senility. Less cancer is found among people who abstain from eating flesh, than among meat-eating people. Consideration of these things is important in the prevention of the disease. The work now being carried on by investigators, it is to be hoped, will soon result in finding the specific cause of cancer and a cure for the disease. Beyond this the hope may be cherished that a specific prophylaxis may be discovered.

Much can be done toward the *prevention of cancer*. Avoidance of those conditions of life which are known to be associated with cancer is of primary importance. As cancer is prone to develop at the site of irritation this cause should be prevented as much as possible. This means chronic inflammations should be cured. Chronic mastitis in the breast is an important example, which if not cured justifies removal of the breast in a woman who has passed the suckling age. Mechanical and chemical irritation, such as from the effect of tobacco smoke on the tongue and throat, holding a pipe much in one position, and the irritation to the tongue or cheek of a sharp-edged tooth, are to be avoided. The scar tissue and chronic discharge, associated with old unhealed laceration of the crevix of the uterus, should be cured as they are prone to give rise to cancer. Gall-stones should be removed for the same reason. When ulcer of the stomach is known to exist, the operation which does no more than gastroenterostomy has failed to remove the most potent cause of cancer. Excision of the ulcer leaves a scar, but the scar of operation is less apt to develop cancer than the scar of a

cicatrized ulcer. Any indurated or inflamed area in which slow extension of localized induration is observed should prompt the consideration of cancer.

Cancer of the esophagus and stomach are intimately connected with the swallowing of slightly diluted alcohol and hot fluids. The avoidance of these two irritants is essential. Hot soups, coffee, tea and other drinks and foods should be avoided.

There are other predisposing or precancerous conditions which should be cured in the interest of cancer prophylaxis. These conditions occurring in persons of the cancerous age, which is especially between forty-five and seventy-five years, warrant surgical removal, or at least they should be watched with suspicion. Among these may be mentioned scars, especially of mucous membrane and mucocutaneous junctions; keloid; the old scars of syphilis, tuberculosis, and psoriasis; myomata; papillomata; elevated angiomata; pigmented moles; adenomata; and acanthosis nigricans.

At present the only cure for cancer is the destruction or the removal of all of the diseased tissues. In the beginning cancer is always a local disease. If the disease is recognized in time, before it has spread to other parts where its presence can not be determined, and the primary growth is all excised, a cure is accomplished and the patient is as free from the danger of cancer as he was before the disease began. It can not be too strongly emphasized, that it is thoroughly proved that cancer is at first a local disease, and if all of the local disease is removed, it is cured. The time at which metastases and involvement of the lymphatics take place in malignant tumors is very variable. In melanosarcoma metastatic deposits often occur before the primary growth has advanced to a size sufficient to be recognized as a growing tumor. On the other hand, in hard scirrhous cancer of the breast several months may pass after the tumor is recognized before the neighboring lymphatic glands become involved. And in some epitheliomata of the skin, the disease may remain distinctly localized for a year or more while it goes on steadily growing *in situ*. When the disease shall be spread through the blood or lymph channels to other parts can never be foretold. We only know that that is the tendency and ultimate result of all cancers if left undisturbed. For this reason as soon as the diagnosis is made or as soon as the suspicion of malignancy becomes well grounded, the disease should be removed.

As a rule the removal of cancer is best accomplished by the knife or other cutting instrument. It is best not to tell a person that he or she has cancer. It is a cruel and depressing bit of information. As a rule it should be given only when consent to operation can be secured in no other way. If a carcinoma does not recur within five years after operation a cure has probably been effected. Usually recurrence takes place within two or three years if it is going to occur. Three years is the limit set down by common experience.

The fact that malignant tumors produce metastases makes it imperative that the primary growth be removed as soon as possible. This is one of the most important dicta in surgery. Its importance should be realized by physicians and the public as well as by surgeons. In no other way so much as by education upon this subject can the frightful mortality of cancer be still further reduced. The technic of removing cancer has reached a high state of perfection, beyond which much progress seems impossible. The further reduction of the mortality must now depend upon earlier operation before metastasis and ineradicable extension of the disease have taken place. There is a crying need of public instruction upon this subject, just as there is for instruction of the public upon the significance of tuberculosis, typhoid, venereal diseases and alcoholism.

Radical operation should be done whenever possible for cancer. That means not only a wide extirpation of the growth itself but, in the case of carcinoma, also the removal of the lymphatic glands of the immediate neighborhood and especially the first groups in the direction of the lymphatic current from the tumor. Sarcoma is often encapsulated, but the limits of carcinoma are never defined. The incision for removal of the latter should be placed fully 1.25 cm. (½ inch) beyond the outermost palpable limits of the growth. If possible the distance should be greater than this. In slow-growing, hard epithelioma it may be less.

Often malignant tumors can not be wholly excised because of their indetermined bounadries, inaccessibility or relation to other structures. In such event the application of the cautery or caustics becomes necessary. The curette is also of service. The *x*-rays and radium give positive results in the destruction of cancerous tissue. The uses of these agencies are described elsewhere. After operation for cancer, if it is thought possible that some disease may have been left, the wound should be exposed to radiant treatment (see *x*-rays and Radiotherapy, Vol. III).

In operating upon cancer it should be borne in mind that the cancer cells are living things and may be transplanted. Therefore, pains should be taken to avoid disseminating these cells. A knife or instrument which has cut through cancerous tissue should be laid aside or boiled before using again. Cancer should not be cut into in the presence of fresh wounds which may become infected. I have seen cancer develop in the abdominal wound after operation for the removal of cancer of the ovary because of violation of this rule. The use of sharp retractors in cancerous tissue is to be deprecated; so also is rough handling or squeezing which may press out into the tissues or lymph stream cancerous cells to become lodged and to grow.

In dissecting out the lymphatics, it is not enlarged lymph nodes alone that should be removed, but all lymphatics in the immediate zone of the disease. Lymph nodes contain cancer cells for a long time before they become palpably enlarged. It is best to dissect out the lymphatics in a mass with the adjacent connective tissue. It is also best to make the lymphatic dissection first, beginning away from the growth and dissecting toward it, and removing the growth last. This can not always be done, as in some situations, on account of the danger of infection, it is better to remove the primary growth and then at a subsequent operation the lymphatics may be dissected out.

After the radical removal of cancer, the patient can not be regarded as cured until the lapse of several years. If the surgeon thinks it probable that all of the disease has been removed, the patient should return for examination every three months during the first three years. About 10 per cent. of recurrences take place after this. I have recently seen a woman with recurrence between the bladder and abdominal wall whom I had operated upon for cancer of the breast eight years before, the patient having remained well and the wound region free from disease all that time. It may be said that a patient who once has had cancer should forever after keep in touch with the surgeon. The possibilities of prolonging life by the surgical treatment of cancer are well proved; but the possibilities of ultimate cure are not so great. Undoubtedly a larger proportion of people, who once have had cancer removed, die of cancer than any figures show.

Charlatanism.—One of the greatest reproaches to society always has been that quacks and charlatans in the guise of physicians, licensed by the State to conserve life and looked to by credulous people to save them, have been willing to commercialize the victims of this terrible malady and prey upon

their suffering. An operable cancer should be operated upon at once. To consume precious time with internal medicines, plasters, etc., is arrant quackery. I have recently operated upon a great ulcerating cancer of the breast with involvement of the axillary lymphatics, which had been treated for nine months with the *x*-rays, from the time when it was a small tumor the size of a walnut, by a man who is permitted to stand high, in the eyes of the public, as a medical practitioner. I have recently seen a similar ulcerating carcinoma which had been treated in the hands of a medical charlatan by the application of kaolin plaster from the time when it was a curable disease to the time when it became incurable. It is pity enough that so many cancers appear in inaccessible regions, or when discovered have progressed too far for extirpation; but the greater pity is that so large a proportion of cancers which are positively curable should not receive the benefits of curative surgical treatment, but pass through the stage of curability in the hands of quacks, and medical charlatans, only to appear before the surgeon, begging for scientific treatment, when money and hope have been squandered. These are the tragedies of surgery. The presence of human vultures, preying upon the credulity of the dying for the sake of money, is the price society pays for maintaining a social system in which most of the important functions are performed for money, and in which health and life are purchasable as objects of barter and trade.

The only operable cancer in which treatment other than operative excision is justifiable is superficial epithelioma of the skin or accessible mucous membranes. Here caustics or cauterants, radium and the *x*-rays are much employed by the dermatologists, and with good results; but even in the majority of these tumors the clean operation with the knife is preferable. Caustics, the cautery, the *x*-rays, radium or some other scientific method must be used in cases in which the patient refuses operation.

Caustics for the curative treatment of cancer are many, and were formerly much used. At present they are employed chiefly in incurable cases. They are usually used after the curette has removed all of the disease down to firm tissue. This curetting should be thorough. *Chloride of zinc* is used in a saturated solution. After curetting away the disease down to firm tissue, the bleeding is stopped by pressure or the actual cautery, and the wound is surrounded with gauze or cotton soaked in a saturated solution of bicarbonate of soda. Pledgets of cotton wet with the zinc solution are packed in the wound, and over these a covering of gauze or cotton soaked with the soda solution which neutralizes the action of the caustic. The depth of the cauterization depends upon the amount of the zinc solution used and upon the amount of neutralizing soda solution. The packing is taken out at the end of a day and a simple antiseptic packing introduced. Better than the zinc chloride, particularly for small wounds, is the *acid nitrate of mercury* in 60 per cent. solution. In using this the disease is thoroughly curetted away and the wound dried even though vessels have to be touched with the actual cautery. Small pledgets of cotton on sticks are then dipped in the mercury solution and the whole curetted field gone over and painted with it. About three coats are applied, left about fifteen minutes, and then neutralized with bicarbonate of soda which is made into a paste with water and pressed into the wound until it is full. This makes a scab and no further dressing is required. The scab should not be removed but allowed to fall off itself as the wound heals. This method is particularly useful in epithelioma of the face, and especially in the region of the inner canthus of the eye. (Other caustics are described on page 73.)

For the treatment of superficial epithelioma of the skin, the dermatologists prefer the *x*-ray, radium or cauterization with acid nitrate of mercury,

arsenious acid, or other caustics. A much used mixture is lysol (2 parts), formaldehyde (2 parts), and ferric perchloride (1 part).

A favorite formula is Bougard's paste which has the following composition:

	Gm. or c.c.	
Farinæ tritici (wheat flour)	30	℥i
Amyli	30	℥i
Acid. arsenos. pulv.	5	gr. viii
Hydrarg. sulph. rub.	2 4	gr. xl
Ammon. chloridi	2 4	gr. xl
Hydrarg. chlor. corros.	25	gr. iv
Zinci chlorid. cryst.	30	℥i
Aquæ fervid	45	℥iss

The first six ingredients are mixed together. The chloride of zinc is dissolved in the boiling water and added to the other mixture during thorough trituration.

A thick layer of this paste is spread on cotton cloth and placed in contact with the growth. It is left on for twenty-four or forty-eight hours. The length of time it is left on depends upon the depth of action desired. In from one to three weeks the slough separates.

Arsenic alone may be applied in Marsden's paste, which is 2 or 3 parts arsenious acid and 1 part mucilage of acacia. This paste acts in from twelve to thirty-six hours. The pain of these pastes may be mitigated by adding eucain or cocain.

Inoperable Malignant Growths.—An operable tumor is one which is capable of being removed by operation. Unfortunately a large proportion of malignant neoplasms when they come to the surgeon are clearly inoperable. Cases which come upon the borderline of operability should be operated upon. A recurrent, painful or breaking down tumor may be operated upon to relieve pain or to prevent ulceration. It is not uncommon for malignant neoplasms to undergo *spontaneous cure.* This is usually observed in ulcerating cancer, in which the most of the growth has ulcerated away. These patients seem to have acquired an immunity which enables them to overcome the small remaining amount of neoplasm. It has also been observed that recovery has taken place after operations which have removed most but not all of the tumor. If the surgeon can remove most of the growth he is justified in operating. But there is rarely advantage and often disadvantage, in removing a minor part of a cancer. As a rule it is best to make these patients comfortable, and permit them to await the end. They should in most cases not be told the nature of their disease.

Palliative Treatment.—Even though a malignant neoplasm cannot be removed there is much that can be done to palliate the symptoms and often markedly retard the progress of the disease.

Curettage may be applied to broken down, ulcerating tumors. If all of the softened and diseased tissue down to firm structures is scraped away, temporary healing-over may be secured, in the place of a discharging ulcer.

Cauterization with the actual cautery accomplishes the same results as the curette, excepting that it can often be carried further and gives rise to less loss of blood. Either the benzin cautery or the electrocautery is used. It is possible to employ the knife cautery to burn out a cancer by a process of dissection. This is the method that was applied so successfully by the pioneer John Byrne in the treatment of cancer of the uterus before the days of hysterectomy. The cautery may also be used to supplement the curette.

Caustics are used in the same class of cases as require curettage and cauterization. A satisfactory treatment of ulcerated cancer is curettage down to solid tissue, followed by drying of the wound, the application of a caustic,

such as zinc chloride or acid nitrate of mercury (60 per cent. solution), and neutralization and protection of the surrounding parts with bicarbonate of soda. For the same purpose acetone is useful. After curetting and drying the surface, acetone is poured over the raw surface, and left for twenty minutes. The surface is then sponged dry, and packed with gauze soaked with acetone. The application of the drug should be made 2 or 3 time as week. Acetone bisulphite may be used as a powder instead of the acetone.

Drugs have always been used internally for cancer but their curative value has never been determined. *Morphin* is of much service in controlling pain, and it should be given freely in incurable cases needing it. *Methylene-blue* seems to have an inhibiting effect upon the progress of cancer, particularly internal abdominal carcinoma. The drug is given by mouth in doses of 0.12 to 0.25 Gm. (2 to 4 grains), gradually increased up to 3 or 4 times daily. It is best combined with an equal amount of powdered nutmeg. It is also of service applied locally to ulcerating cancer. *Pyoktanin* is similarly used internally in 0.12 to 0.25-Gm. (2 to 4-grain) doses, and externally pure or in solution. These anilin solutions are also injected into the tumor in solutions of the strength of 1 : 500 or stronger. Injections are made twice weekly into different parts of the growth. If painful they may be combined with a local anesthetic and morphin. *Arsenic*, because of its power to increase metabolism, has long been employed. It is possible that it has an inhibiting effect upon the growth. The bromide of arsenic is used internally in doses of 0.0015 to 0.006 Gm. ($\frac{1}{40}$ to $\frac{1}{10}$ grain) after meals, and the carbonate of calcium in 0.6-Gm. (10-grain) doses before meals. *Salvarsan* and *neo-salvarsan* have acted favorably in retarding the growth of cancer in some cases. These drugs are not to be thought of as curative.

Erysipelas toxins have the power to cure some cases of sarcoma. Spindle-celled sarcoma is most susceptible to their influence, round-celled sarcoma but slightly, and carcinoma probably not at all. It has long been known that in certain cases of sarcoma, when erysipelas developed in the patient, the tumor disappeared. Fehleisen injected cultures of erysipelas bacilli into neoplasms. Lassar and Spronk made cultures and secured the toxins by sterilization and filtration. Coley has perfected these principles. His method is to make cultures of erysipelas cocci in broth, to inoculate the cultures after three weeks with *Bacillus prodigiosus*, to cultivate the mixed growth for four weeks, and then to subject them to a temperature of 58°C. (for about an hour) until the microörganisms are all dead. This fluid is injected near the sarcoma in doses of from 0.15 to 0.5 c.c. (2 to 8 minims). Fever and toxic reaction follow the injection. Treatment is given about every three days. This method is well worthy of trial in inoperable spindle-celled sarcoma. Its use is justifiable in other malignant growths, although the results are very uncertain. Serum from erysipelatous animals is also of service. The removal of sarcoma, even though the operation seem complete, should be followed by treatment with the mixed toxins of erysipelas and bacillus prodigiosus immediately after the operation.

Serums of animals which have an acquired or natural immunity to cancer have been experimented with and found to possess an immunizing and curative property. Sterilized products of *cancer* itself have been injected with apparent benefit in some cases. Bestowing an *immunity* is possible in some animals by inoculating with an attenuated growth. That some of these methods may be successfully applied to man should be one of our fondest hopes.

The *x-ray*, *fulguration* and *thermoradiation* have positive curative value in superficial epithelioma. They may be used in inoperable superficial cancer to promote external healing (see Radiotherapy and Thermoradiation, Vol. III).

Radium has a curative influence upon cancer. It can be applied to deep growths. It has an inhibitive effect upon the progress of inoperable cancer (see Radiotherapy, Vol. III).

Radiation therapy, with *x*-ray, radium, and other radiant substances has been so perfected that some surgeons are using it in many forms of operable cancer in the place of the knife. Thus in the clinic at Freiburg radiation treatment of cancer of the uterus had entirely superseded the treatment by hysterectomy; and in myoma of the uterus in women over forty years of age. Cancer of the stomach may be favorably influenced by the *x*-rays and secondary deposits in the liver may be made to cicatrize, and large doses of radium, strongly filtered, are of benefit in cancer of deep-seated organs. The radiotherapeutists believe that when a cancer is yet operable, and can be easily controlled by touch and sight, radiotherapy should first be applie d, and if this is not successful operation should be resorted to; when the case is operable but not easily controlled by sight and touch, operation should be done, provided the operative mortality is low and the chances for an ultimate cure are good, otherwise radiotherapy should be employed; when the case is inoperable, radiotherapy should be used; and when a case has been cured apparently by operation or radiation, prophylactic radiotherapy should be applied at regular intervals. This teaching leans too strongly toward radiotherapy as a curative agency. It is the opinion of the author that radiotherapy should be reserved for those cases which are not amenable to radical operative removal, and that there are few cases of cancer that can be cured by radiotherapy that can not be cured by surgical extirpation.

The *starvation treatment* of cancer consists in tying the arteries which go to the growth. If all of the available arteries supplying a tumor are tied the growth is retarded, but not cured. This principle has been applied to incurable cancers in which a prolongation of life was desired. It has given place to the more effective radiotherapy. The *serum treatment* of cancer, first studied by E. Hodenpyl, has so far not given encouraging results. Injections with pleuritic, ascitic, and other serous fluids, taken from the same person or from another cancer patient, have some effect upon the growth, but not to a degree that would justify regarding them as curative.

Treatment with the tissue juices of human fetuses, mixed with salt solution, has given results similar to the above. It is possible that these methods may some day be perfected and made effective.

The *peripheral injection* of boiling water, liquid paraffin, pyoktanin, and other substances, to set up a barrier of reaction beyond which the growth could not go, has been successful in some cases: A solution of 5 parts of potassium hydroxide, 4 parts sodium hydroxide, and 1000 parts distilled water, injected daily in amounts of 1 or 2 c.c. (15 to 30 minims) about the growth, has been used with similar results.

The *trypsin* treatment consists in injections of a 2 per cent. solution of trypsin in doses of 2 c.c. (30 minims) into the region of the growth or in the gluteal muscles. Such injections are made every two or three days. The results have been doubtful; which means that as these cases often show fluctuations, it is difficult to determine whether an apparent cessation or recession of the disease is due to a given treatment or is due to the rapid advance of secondary deposits elsewhere in the body or other unknown causes. One thing is known, and that is that none of these palliative measures, which it has been hoped might be curative, can be used in any case of cancer with the expectation that it will effect a cure.

(Tumors, benign and malignant, of special structures, tissues and regions, are discussed under their respective heads.)

BLOOD AND BLOOD-VESSELS

HEMORRHAGE

Hemorrhage comes from arteries, veins, capillaries, sinuses, or from the heart itself, and follows the rupture or wounding of these structures. Hemorrhage from one or more of them may be combined with capillary bleeding. It is usually not necessary to resort to artificial means to control hemorrhage because in most instances bleeding naturally stops. Were this not so animals and man would soon bleed themselves extinct.

Hemorrhage is borne very poorly by young children, old people, persons of low blood-pressure, those exhausted by disease, alcoholics, and victims of infective diseases; and they should be spared as much as possible the loss of blood.

The **natural arrest of hemorrhage** depends upon (1) the coagulation of blood, (2) the contraction and retraction of the walls of wounded blood-vessels, (3) the lowering of blood-pressure by the diminution of the volume of blood and the weakening of the heart by anemia, and (4) the increase in the coagulability of the blood as anemia progresses. These are the life-saving provisions of nature, all of which come to the aid of the surgeon in his efforts to control hemorrhage.

FIG. 186.—GAUZE PACKING IN WOUND TO CONTROL HEMORRHAGE.

The Surgical Arrest of Hemorrhage.—Hemorrhage from a vessel, too large to be controlled by nature, from multiple vessels or in the case of deficient coagulability should be controlled artificially. Indeed, all hemorrhage should be checked if possible by the aid of artificial means.

Pressure is the most useful and easily applied hemostatic agency. It may be applied directly *at the bleeding point.* If this is done, as much consideration for the asepsis of the wound should be had as the emergency will

permit. In operative wounds, pressure made with gauze, the finger or a retractor after a few minutes will be found to have arrested the bleeding from small vessels. Bleeding from a large vessel is controlled by pressure while arrangements for its ligation or permanent control are being made. No person should bleed to death nor be permitted to lose much blood from a wounded vessel which is accessible to pressure. For permanent pressure, wounds may be packed tightly with gauze held in place by the pressure of the bandage (Fig. 186). Hemorrhage is also controlled, particularly if arterial, by pressure *upon the trunk of the artery* supplying the part. This may be made by a tourniquet. Such a tourniquet may be extemporized of cloth or rope (Fig. 186*a*). Or compression may be made directly or with the fingers.

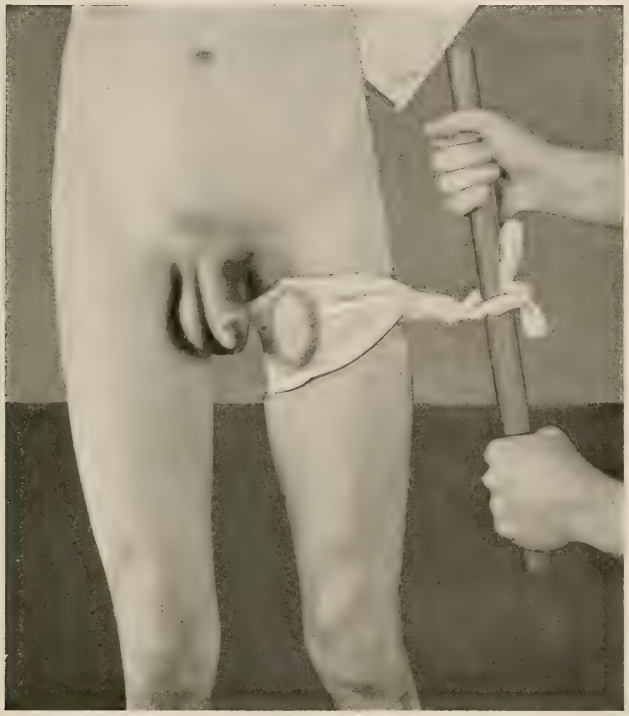


FIG. 186*a*.—IMPROMPTU TOURNIQUET, MADE OF HANDKERCHIEF AND STICK, APPLIED TO THIGH.

A pad is placed over the femoral artery to increase the local compression.

Forced flexion of a joint with fixation of the limb in extreme flexion angulates and compresses the artery and diminishes the blood supply beyond. *Forced extension* of a joint accomplishes the same thing by compressing the artery against the bony prominences of the joint.

The **ligature** is employed to tie divided vessels. The vessel, if cut in a wound, is caught with forceps or a needle and tied with the ligature, the ends being cut off (Fig. 187). The ends should not be cut so short that the knot may come untied. Ordinarily the ends left should be about 5 to 10 mm. (¼ inch) long. The ligature is also used in a curved needle and passed around a bleeding point in the form of a purse-string where the bleeding

vessel is not freely exposed or where there is not enough of the vessel to hold a ligature without slipping (Fig. 188). In tying ligatures the bleeding vessel should first be clamped, the surgeon being sure that the bleeding is controlled, and the ligature is then tied around the vessel while the clamp holds it (see Artery Clamps). The knot should be a square knot, and if the

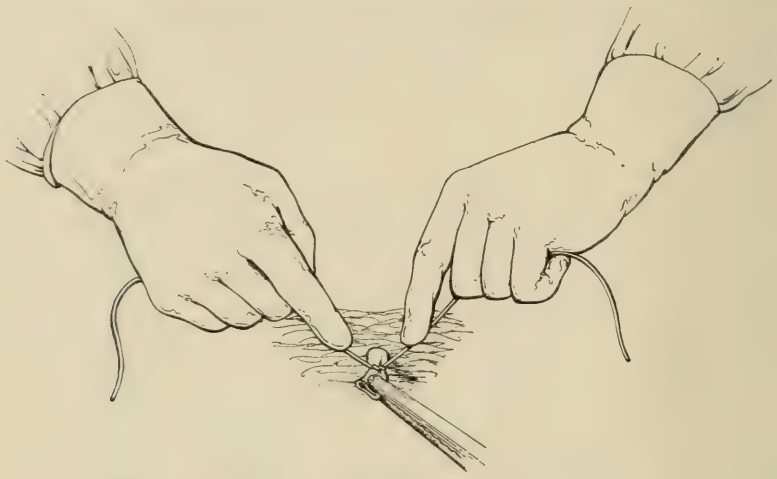


FIG. 187.—CUT END OF ARTERY IN WOUND, WHICH HAS BEEN SEIZED BY CLAMP, AND IS BEING TIED WITH A LIGATURE.

vessel is large a third tie should be made for safety (see Knots). The clamp should not be taken off until the knot is tied and the ends of the ligature cut off. The first turn of the knot should be tight, the subsequent turns should be moderately firm; if they are tied too tightly they may cut and break the thread. In operative wounds it is customary to clamp vessels with hemo-

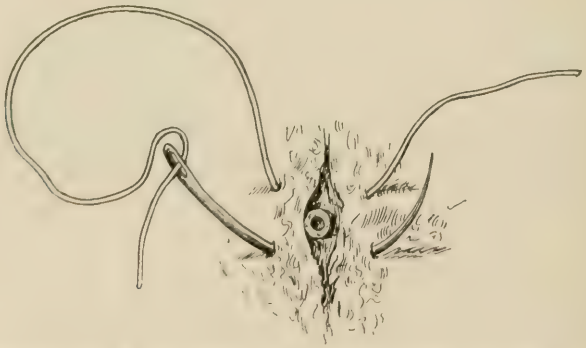


FIG. 188.—CONTROLLING BLOOD-VESSELS BY SUTURE PASSED AROUND IT WITH NEEDLE.

static clamps as fast as they are cut, and leave the clamps hanging in the wound until an opportune time when they are tied. Or an assistant is assigned to the duty of tying vessels and removing clamps, while another assistant applies clamps as fast as the surgeon cuts vessels. A good assistant applies the clamp only to the vessel; a poor assistant clamps a mass of tissue with the vessel. A good assistant applies the clamp at once after the vessel is cut, often he sees the vessel before it is cut and clamps it in two places as the

surgeon cuts between; a poor assistant does much sponging to clear the field of blood, which he has allowed to accumulate, before making a plunge with his clamp in the direction of the hemorrhage.

In tying a *mass-ligature*, or a ligature about a pedicle containing other tissue beside the vessel, skill and experience are required to make a secure knot. A single tie slips before it can be made double. If the first tie is held with forceps there is danger of injuring the thread. This difficulty may be overcome by passing the ligature loosely twice around the pedicle; a single tie is then made; one end of the ligature is then passed under the loop made by the double turn around the pedicle; as the single knot is then tightened by drawing the ends of the ligature, the loop is drawn down upon the knot and prevents it slipping (Fig. 189). A tie is then made over the loop, and another on this to make a square knot.

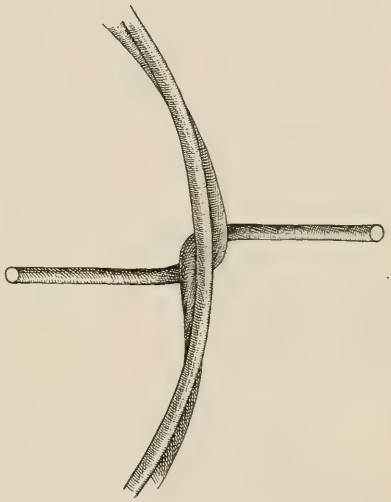


FIG. 189.—SHOWING METHOD OF LIGATING LARGE PEDICLES.

The first half of knot is tied and drawn under the extra turn of the ligature which presses upon it and holds it.

Large vessels, such as the carotid and femoral arteries, require especial attention. If the ligature is tied too tightly, it lacerates the inner coats, the wall of the vessel is greatly weakened, and rupture of the vessel at the ligature may take place. This is very apt to occur in such a vessel as the common iliac. On the other hand, if the ligature is not tied tightly enough the constant pulsations from the heart, hammering away at the closed end, may roll off the ligature. This latter danger is overcome by passing the ligature around the vessel with a curved needle, catching the perivascular connective tissue, and then tying it as the artery is drawn down with forceps. This should be the rule in tying large arteries which have been cut across.

In the case of great vessels with high pressure, a single strand of round catgut makes pressure on too narrow an area. Several strands, lying side by side, should be separately tied.

Ligatures are also placed on arteries in their continuity to control bleeding (see Ligation of Arteries). In tying large vessels the first tie should be made tightly. It need not be so tight as to rupture the inner and middle coats of the vessels as is commonly taught. The vessels should be cleanly isolated before tying. The best material for ligatures is catgut. For small vessels it need last only a day or so for large vessels it should last for a week. The size of the catgut used for ordinary ligatures is No. 2. No. 1 is used for small vessels; No. 3 and No. 4 are used for tying the largest vessels and thick pedicles. Chromicized or silver catgut in smaller sizes is preferable for tying vessels than plain catgut of a larger size. As soon as a vessel is tied, particularly if the intima has been roughened by curling in of the coats, stasis and coagulation take place. A clot forms at the site of ligation and may extend back to the first branch that goes off. The intima becomes adherent. The clot becomes organized. When an artery is cut in two, if the collateral

circulation is established before a firm clot has formed in the distal side, bleeding will continue from the distal opening even though the proximal side is ligated. Both sides of a divided vessel should be ligated. This rule applies to veins as well as arteries. A small wound in a vein does not require ligation of the whole vessel but simply the wound may be ligated (Fig. 190). Larger wounds, even complete division of the vessel, may be repaired by suture. This is done both in arteries and veins. The lateral suturing of wounds is practicable and also end-to-end anastomosis (see Wounds of Veins and Arteries).

Ligatures for small superficial vessels should be about 26 cm. (10 inches) long. For larger or deeper vessels they should be longer. In the interest of economy, where a number of vessels are to be tied, the surgeon should take in his hand a spool of thread and tie from the end of that.

In aseptic wounds, ligatures should be tied by gloved hands, because in few other functions so much as in tying ligatures are the contents of skin follicles and finger chinks squeezed out. Not only catgut but silk, linen, cotton and other materials may be used. Catgut is preferable because it is absorbable and does not leave a foreign body in the wound. It possesses the disadvantages that if it is infected it is similar to necrotic sloughing itssue; and a knot tied with catgut slips more easily than a knot tied in non-absorbable material. In ligating vessels care should be taken not to include a nerve of much size in the ligature.

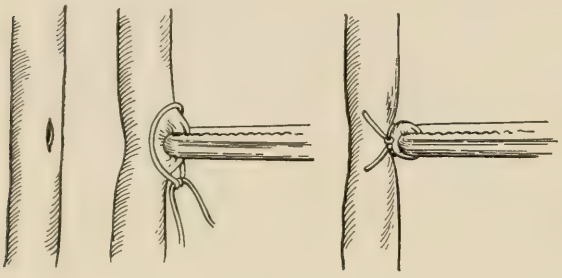


FIG. 190.—LATERAL LIGATION OF VEIN.

There are certain rules for the ligation of **wounded arteries** which have grown out of experience. These rules apply only to vessels in which suture of the vessel to preserve its lumen is not called for.

1. In the case of primary hemorrhage those vessels should be ligated which are bleeding; and vessels which can be seen pulsating in the wound, even though plugged by a clot, should also be tied.

2. Arteries which are completely divided should be ligated above and below the wound; arteries which are wounded but not divided should be ligated above and below it .

3. Ligation in the continuity of the artery outside of the wound is not to be done except in cases in which the artery at the wound is more inaccessible than it is at some point between the wound and the heart, in cases in which the nature of the injury renders it inadvisable to disturb the wound, and in cases in which the wound is known to be seriously infected, and a clean operation can be done nearer the heart.

4. When practicable it is always best to ligate in the wound, because the bleeding artery can be seen, and if ligation in the continuity of the vessel is done bleeding may still come through the collateral circulation.

5. A large artery, wounded near its origin, should be tied beyond the wound; and the trunk, of which it is a branch, should be tied above and below the place of exit of the wounded artery.

6. Any branches emerging from a wounded artery between two points of ligation should be tied.

7. The main artery should not be ligated when the bleeding is from a branch which can be controlled.

Absorbable metal clips are used to close blood-vessels. Such clips have been made on the principle of the clips used for closing skin wounds. Magnesium is a metal which absorbs rapidly. One of its disadvantages is that it is brittle. E. W. Andrews worked out an alloy which answers this purpose, and eliminates the objections inherent in magnesium.

Cold has the power to check hemorrhage by causing contraction of the blood-vessels and other tissues, and by increasing coagulability. It is not much used but in emergency may be of service. Very cold water may be introduced into a wound; or a lump of ice which has been washed in running water, rinsed in sterile water, and wrapped in sterile gauze may be inserted in a wound. When such measures as this can be employed, usually compression by gauze packing is more practicable.

Heat is one of the oldest hemostatic expedients. Before the ligature was introduced into surgery by Ambroise Paré, bleeding from wounds was staunched by pouring in hot oil. A moderate degree of heat—49° to 60°C. (120° to 140°F.)—does not devitalize the tissues but hastens coagulation of blood and stimulates the vessels to contract. Towels wrung out in hot water with a stupe wringer are pressed into large wounds where there is much capillary oozing, as in amputations; and even in smaller wounds hot sponges are of service. The surrounding skin should be protected from burning. A higher degree of heat applied with boiling water or steam is sometimes used where hemostasis and disinfection are to be accomplished at the same time. *Live steam* may be conducted from a boiling vessel through a pipe into an osteomyelitis cavity which has been cleaned out or into a bleeding infected wound or uterus. When steam is conducted into a closed cavity an exit tube should be provided and the surrounding parts protected from the heat. Heat may be engendered in such a wound by filling it with water or olive oil and then heating the fluid by means of the cautery.

The **cautery** is one of the most effective hemostatics. It consists of a rod of metal the end of which is heated to a cherry red (white heat is not so effective), and applied to the bleeding vessels or tissues. A simple rod of iron was formerly used and heated in a charcoal brazier. The modern cautery is heated by electricity or by the combustion of a volatile fuel inside of the cautery metal (Fig. 27). It is of especial value in capillary oozing, where tissue is friable from disease, or where cancerous, sloughing or infected tissue is to be removed or in controlling the hemorrhage of hemophilia. The cautery not only furnishes heat to coagulate the blood, but it carbonizes the clot and the tissues which it touches, converting them into a hard, sterile charred crust.

Electricity is used as a hemostatic to heat the electrocautery and to add the coagulating effect of the electric current to heat and pressure. An instrument for *electro-hemostasis* consists of heavy hemostatic clamps which grasp a pedicle or vessel, and which are so constructed that a powerful electric current is passed down one blade through the compressed tissue and back through the other blade (Fig. 191). The tissue is slightly charred by this process. It is possible to use this instrument not only upon single blood-vessels but also upon pedicles such as the Fallopian tubes, vermiform appendix and ovarian tumors, no further ligation being required.

Crushing (angiotripsy) depends upon applying pressure to the walls of vessels until the walls adhere and close the lumen. The ordinary hemostatic clamp applied to a vessel, if the vessel alone without surrounding tissue is clamped, acts as an angiotribe; and, if the vessel is not large and the blood-

pressure not high, when the clamp is taken off after a few minutes, it will be found that bleeding does not recur. The clot that has formed between the clamp and the first branch above, combined with adhesion of the intima caused by the crushing together of the lining surfaces of the vessel, constitute an insurmountable barrier against the internal blood-pressure. For crushing

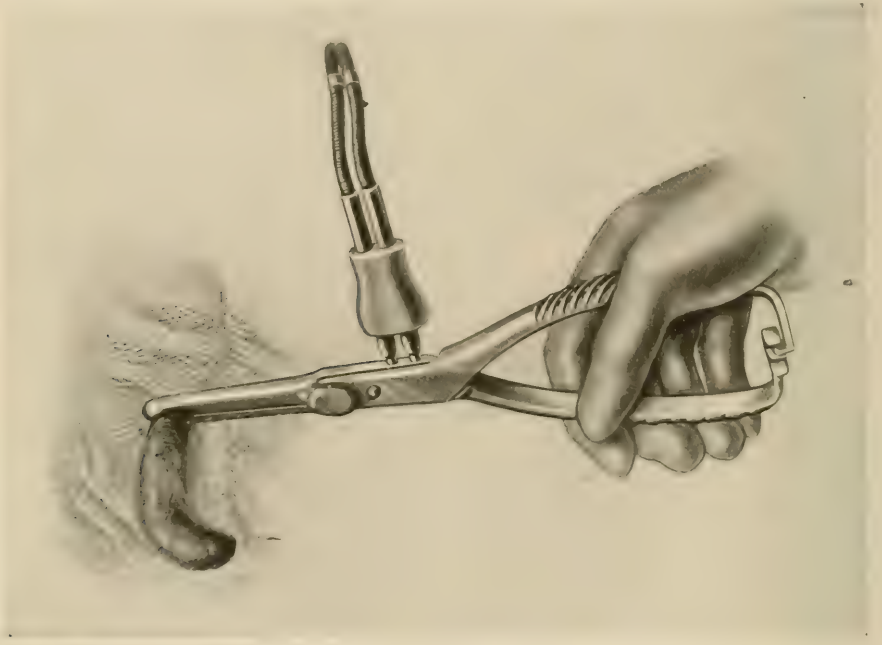


FIG. 191.—ELECTROHEMOSTATIC CLAMP.

The clamp is shown grasping an inflamed vermiform appendix, which it crushes. When the current is turned on the crushed part is burned and coagulated by the strong current.

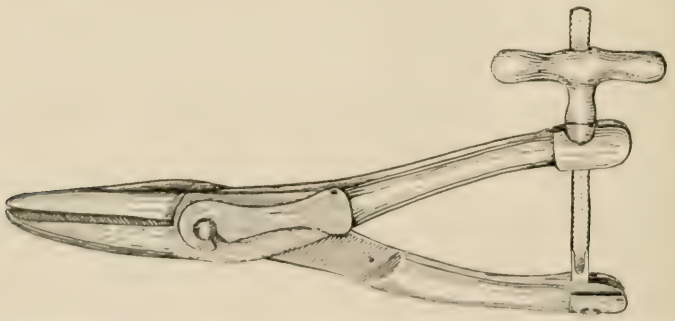


FIG. 192.—ANGIOTRIBE FOR APPLYING POWERFUL LEVERAGE IN THE CRUSHING OF BLOOD-VESSELS.

larger vessels and pedicles a more powerful instrument called the *angiotribe* is used (Fig. 192). This has an enormous crushing power. When applied to pedicles it may be supplemented by the ligature. In removing the appendix vermiformis, ovarian tumors or the uterus, after crushing with the angiotribe, the pedicle may be divided by burning it through on the distal side with the cautery.

The **electrocautery** and the **angiotribe,** applied to *pedicles* is not as good surgery as the use of the ligature. They have no especial advantage; and they do possess the disadvantages that unnecessary tissue is devitalized and large vessels are not so securely closed. It is better surgery to be familiar with the important vessels of the part, isolate them, and tie each separately with chromic catgut. Crushed and burned tissue is just as much foreign material and dead matter as catgut is; the difference is that the angiotribe and the electrocautery leave more of it in the wound than does the ligature.

Acupressure is pressure made by means of a pin passed through the tissues near the vessels, the vessel either being pinned in compression or compressed by winding a ligature around the pin.

Elevation of the bleeding part helps to diminish blood-pressure at the bleeding point.

Torsion consists in seizing the cut end of a vessel with a hemostat, drawing out the vessel and twisting it two or three or more turns until its inner coats are broken (Fig. 193). In general operative work small vessels are twisted and large ones tied. A rule is to twist the vessels, the names of which are not known to the surgeon.

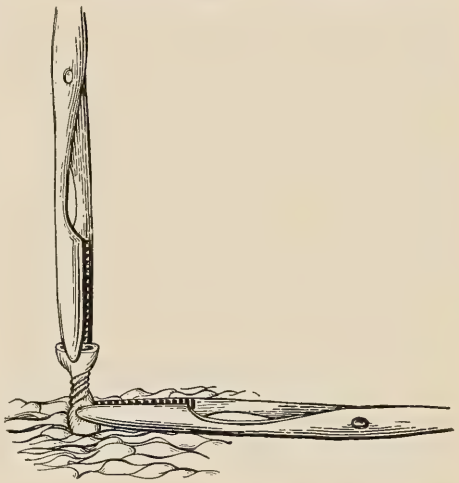


FIG. 193.—TORSION APPLIED TO DIVIDED ARTERY.

The stump of the vessel is twisted while it is held by another clamp. In smaller vessels this latter clamp may be omitted

Styptics and **astringents,** once much used, are now but little employed in surgery. Pressure and ligation have superseded them. Occasionally in oozing wounds in which the more desirable methods are unavailable, styptics or astringents may be used. Usually they are employed in solution or in gauze. They are chemicals which have the power of rapidly and firmly coagulating albumin, and at the same time causing contraction of animal tissue. They tend to form a firm clot and at the same time make smaller the mouths of the bleeding vessels and constrict the surrounding tissues. The chief agents of this class are the following: gallic acid, tannic acid, trichloracetic acid, alum, antipyrine, copper sulphate, hydrastis, hydrogen peroxide, ferric chloride, iron sulphate, lead acetate, manganese sulphate, oil of turpentine, silver nitrate, silver citrate, stypticin, acetic acid, chromic acid, picric acid, aluminum acetate, aluminum sulphate, bismuth subgallate, bismuth subiodide, bismuth subnitrate, cadmium acetate, cadmium sulphate, copper acetate, copper sulphate, potassium bichromate, zinc acetate, zinc sulphate, catechu, hematoxylin, kino, krameria, hamamelis and other tannin-containing drugs. Gauze wet with 5 per cent. acetic acid solution or with 2 per cent. lead acetate solution and packed into a wound has a decided hemostatic effect. Subgallate of bismuth powder dusted upon oozing surfaces is also effective.

Locally **adrenalin chlorid** is of more value in surgery than all of the above astringents. It has the power of contracting blood-vessels by action upon their nerves when applied in a wound, to a mucous membrane, injected hypo-

dermically or taken internally. It is used locally in strengths varying from 1 : 10,000 up to 1 : 1000. The amount of the latter strength which may be absorbed by an adult without harm is 0.6 to 1.2 c.c. (10 to 20 minims). Its action is not prolonged, being from twenty minutes to an hour or two, depending upon the quickness of the local circulation. It is supplied sterile so that it may be used in wounds. Its astringent action is so great that it actually produces a blanching of the tissues. Bleeding from only fairly large vessels will take place in its presence. It is used to produce local anemia in operations upon mucous membranes; it is combined with cocain and other analgesics for local hypodermic use; and it is applied on a swab directly to bleeding surfaces. It is one of the most valuable drugs in the surgeon's armamentarium.

The use of **blood-serum** or **blood** of another person applied at the bleeding point hastens coagulation. The surgeon in emergency may test this in the presence of a hemophilic wound, by making a small wound in himself and allowing the blood to drop into the wound of the patient. The cessation of bleeding is marvelously prompt.

In hemorrhage of the newborn and in hemophilia, these expedients are most useful.

Fibrin clot results from the action of **thrombin** (called fibrin ferment) upon fibrinogen in the presence of calcium. Fibrinogen and thrombin are normal and constant constituents of the blood. A sterile, friable, anhydrous powder, which is soluble in water in a concentration of twice that of normal serum, is precipitated from horse and rabbit serum. This powder may be applied directly as a local styptic to bleeding surfaces or dissolved in water. The amount of water required is less than half that of the serum from which the powder was precipitated. The dose for injections is 0.6 Gm. (10 grains), which is equivalent to 10 c.c. (160 minims) of whole serum. From 10 to 40 c.c. (⅓ to 1⅓ ounces) are given daily.

In emergency antidiphtheritic or antistreptococcic serum may be used in the treatment of hemorrhagic diathesis. While the serum of dogs, cows and oxen have a curative value, they seem to have additional toxic properties to man, and should be avoided.

A tissue extract, called **thromboplastin,** is a fine suspension and solution of macerated ox brain in normal salt solution with 0.3 per cent. of tricresol added as a preservative (A. F. Hess: Jour. Am. Med. Assoc., Dec. 9, 1916). This substance must be brought into direct contact with the bleeding surface. If clots are present they should be removed. In hemophilia it seems to act with remarkable efficiency.

A similar preparation called **kephalin** is made commonly from the brains of hogs or other animals. Gauze impregnated with this substance has marked hemostatic properties. Sterilization by heat does not seem to deteriorate it.

The local application of **muscle, fascia,** or **fat** will check bleeding in parenchymatous organs. Muscle is most effective. Bleeding from the liver, kidney, spleen or prostate is quickly checked by snipping off a piece of muscle in the adjacent wound and pressing it upon the bleeding surface. The transplanted tissue may be sewed in place to cover the bleeding area.

In operating on the brain bleeding often may be controlled by snipping off a bit of temporal or occipital muscle and placing it on the bleeding point.

Coagulants, or agents which have the power of increasing the coagulability of the whole mass of blood, are most useful, not only in uncontrolled bleeding in normal persons, but especially in the presence of abnormally reduced coagulability.

The **transfusion of blood** is a most valuable means of treating uncontrolled oozing due to retarded coagulability. In hemophilia it is the most highly effective treatment.

The **injection of defibrinated blood,** preferably from one of near kinship, is most valuable in hemorrhagic diathesis. Such injections may be made into the tissues. A dose of 40 c.c. (1⅓ ounces) is potent for good. Blood may be drawn in a sterile vessel and allowed to stand in an ice box until the serum separates. Standing blood, however, rapidly loses its coagulating power. A dose as small as 10 or 20 c.c. (150 to 300 minims) is effective. Doses which are too large seem to have no effect. In the event of emergency blood from one person may be injected fresh directly into the tissues of another. Serum of horse, rabbit or sheep may be used, and seem to be as effective as human serum. In hemorrhagic disease of the newborn the hypodermatic injection of 5 c.c. of rabbit serum usually has an instantaneous effect in checking bleeding.

Gelatin increases the coagulability of the blood. It is of some use given by mouth. Locally it is applied in a strength of 5 per cent. in sterile salt solution (see Gelatin, page 347).

Hypodermatically gelatin in doses of 30 c.c. (1 ounce) of a 1 per cent. solution alleviates the pain of aneurism. In secondary hemorrhage 500 c.c. (1 pint) of the same solution may be injected deeply into the tissues of the back or buttock.

Calcium, in the form of the chloride, given by mouth, is said to have the power to increase the coagulability of the blood; but if given for more than four days it *diminishes* the coagulability of the blood. From 1 to 2 Gm. (15 to 30 grains) are given in an initial dose, and then 0.3 gm. (5 Grains) every hour for six doses per day. The *lactate* of *calcium* is more soluble, and may be given in doses of 2 or 3 Gm. (30 to 45 grains) daily to adults. The coagulability of the blood is said to be increased within an hour, and the increase lasts for several days. My own experience with these drugs does not corroborate the claims for their value as coagulants.

Surgical Anemia.—Loss of blood from hemorrhage produces what is called surgical anemia. If it continues it is fatal. The amount of blood which an individual can lose before death results is very variable, and depends upon the general resistance and upon the rapidity of the hemorrhage. A rapid hemorrhage may be fatal, whereas the same amount of blood may be lost slowly without danger. The important rule in the treatment of hemorrhage is that *general constitutional treatment should not be instituted before the local treatment has been applied to stop the hemorrhage.* When we recall the effort which nature makes to check bleeding (the weakening of the heart, the lowering of blood-pressure, and the formation of plugs in the mouths of the vessels), it becomes apparent that the salutary benefit of these natural life-saving efforts to check hemorrhage should not be sacrificed until we can substitute something better and accomplish by artificial means a staunching of the flow of blood. To give cardiac stimulants, infusions and other blood-pressure-raising treatments, before the vascular leak has been controlled is one of the greatest sins that can be committed against a bleeding person. First rapidly stop the hemorrhage by the quickest possible expedient (pressure, the tourniquet, or the clamp); be sure that it is stopped; and then direct attention to the next most important emergency to be met. The treatment of the anemia should be aimed to increase the volume of circulating fluid, to stimulate the vital centres at the base of the brain, to furnish oxygen to the tissues, and to restore the lost blood cells by good hygiene after the other conditions have been met. A

slight degree of anemia requires no special constitutional treatment; plenty of fresh air and fluids, and the ordinary food, suffice to restore the patient to a natural state. No didactic instruction can teach when infusion and transfusion are indicated. In general, when a patient's pulse-rate as a result of hemorrhage goes above 140 or 150 per minute and there is air hunger and thirst, the radical measures for the treatment of anemia are called for. Restlessness is a symptom of extreme anemia and should not be waited for. After the hemorrhage has been stopped measures for the treatment of acute anemia are called for.

Fresh air is of importance to furnish oxygen to the anemic tissues. In lieu of fresh air, compressed oxygen may be used.

Lowering the head causes gravitation of blood to the brain and stimulation of the vital centres. This is accomplished by elevating the foot of the bed as much as is consistent with the comfort of the patient.

Artificial anemia of the extremities is induced by bandaging snugly with flannel or rubber bandages from the toes to the pelvis and from the fingers to the shoulders, thus expelling the blood from the extremities and adding it to the circulation of the head and trunk. These bandages should not be left on long for fear of ischemic paralysis or gangrene; but the method is of service in emergency while means to increase the amount of circulating fluid are being gotten ready. As coproclysis, hypodermoclysis, infusion or transfusion is being applied the bandages are removed slowly from one limb at a time.

Measures for Adding Fluids to the Body.—Measures for adding fluids to the body are important, not only in shock and hemorrhage, but in many other conditions in which the fluids added may convey into the circulation some needed constituent. These measures are employed not only to add bulk to the bodily fluids, but they are also used to promote elimination. Their field of usefulness is very great and embraces a large number of diseases and conditions.

Fluids by mouth pass through the stomach and are quickly taken up by the intestine particularly when the amount of circulating fluid is below normal. In acute anemia patients should be given water freely. Also in all toxic conditions water is necessary to dissolve out the toxins and expedite their elimination.

Proctoclysis (coproclysis) or rectal infusion is one of the most valuable means of adding fluid to the body. When normal salt solution (0.6 per cent. is used, it may be made of sodium chloride and warm water. It is quickly obtained by adding 4 Gm. (a teaspoonful) of table salt to 700 c.c. (1½ pints) of water. If the bleeding has surely been controlled 0.6 to 1.2 c.c. (10 to 20 minims) of adrenalin chloride solution (1 : 1000) may be added to it. The fluid is injected into the rectum or is allowed to flow in slowly. This may be repeated at intervals as indicated.

Proctoclysis takes advantage of the absorptive power of the lower bowel. A small catheter is best introduced into the rectum, and the salt solution allowed to run in drop by drop. By this means it is absorbed as fast as it flows, and the blood-pressure is continuously maintained. It is practical when there is less urgency than to demand intravenous infusion (see Proctoclysis, Vol. III).

Hypodermoclysis is the subcutaneous injection of fluid to be taken up by the lymphatics of the connective tissue. A sharp-pointed hollow needle, connected by rubber tubing to the vessel containing the fluid is thrust into the connective tissue under the breasts, in the front of the thighs, the pectoral or scapular regions. The needle should be moved about somewhat and

massage applied in the more dense tissues. Under the female breast the fluid is readily absorbed (Fig. 194). Normal saline solution at a little above body temperature is used. Injections in several different places or in different directions is necessary to prevent too great tension and sloughing. This operation is not painful if the tension is not great. It is practised when the condition is not so grave as to require intravenous infusion and when for some reason proctoclysis can not be used. The same amount of fluid is used as in infusions.

FIG. 194.—HYPODERMOCLYSIS.
The fluid flows by gravity into the connective tissue under the breast.

Hypodermoclysis is of especial value in acute anemia and shock. Adrenalin chloride 0.6 to 1.2 c.c. (10 to 20 minims) of the 1 : 1000 solution may also be used here.

Continuous hypodermoclysis was advocated by A. B. Kanavel (Surg., Gyn. and Obs., Oct., 1916). A small needle, No. 20, about 10 cm. (4 inches) long, is used. Painless insertion of the needle may be secured by injecting a local anesthetic with a very fine needle. After passing the needle into the subcutaneous tissue of the pectoral region, the needle is immobilized by an adhesive plaster strip, a pad of gauze being placed between the head of the

needle and the skin. The solution is allowed to flow slowly, never causing painful distention of the tissues. This may be kept going continuously for several days if necessary. The first appearance of subcutaneous edema calls for temporary discontinuation of the flow.

Intracellular infusion may be made also in any connective tissue spaces. The *pubovesical space* lends itself especially for such injections. With a needle passed behind the pubes, 1000 c.c. of fluid easily flows into this space.

Intra-abdominal saline infusion is employed at the termination of aseptic abdominal operations. It consists in leaving in the abdomen 500 or 600 c.c. (1 pint or more) of salt solution for absorption by the peritoneum, and closing the abdomen.

Intravenous infusion throws the fluid directly into the circulation. It is a most useful expedient in combating shock and acute anemia, and is particularly useful when rapid elimination of toxins is desired. It acts by at once increasing the volume of circulating fluid. The fluid is rapidly lost through the kidneys, the cellular tissues, and other excretory organs, and repetition of the infusion often becomes necessary. Intravenous infusion is done as follows:—About 500 or 1000 c.c. of sterilized normal salt solution is prepared at a temperature of 46°C. (115°F.). To maintain its temperature it may be kept in a vessel of water at 49°C. (120°F.). A subcutaneous vein near the bend of the elbow is exposed under local anesthesia, by an incision in the direction of its long axis. The vein is quickly isolated, and two ligatures passed under it, but not tied. It is then picked up with delicate forceps, nicked with sharp-pointed scissors and the canula, connected with the infusion jar, slipped in the direction toward the heart (Fig. 195). As soon as the canula enters the lumen of the vein the ligatures are tied. The lower one, occluding the vein, is tied in a permanent knot; the upper one is tied down upon the canula in a single knot ready to be tied permanently after the canula has been withdrawn. Before inserting the canula the fluid should be allowed to flow so that the cooled fluid in the tube escapes.

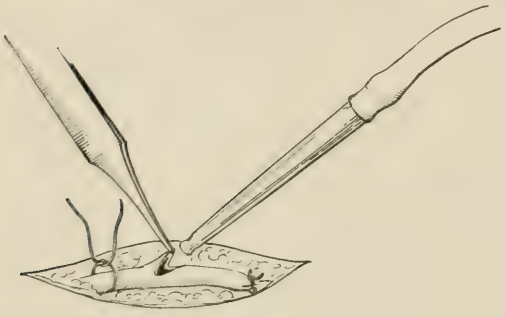


FIG. 195.—INTRAVENOUS INFUSION.
Showing vein held with forceps, opened by cut with scissors, and canula about to be slipped in.

The solution as it runs into the vein should have a temperature of from 39° to 46°C. (102° to 115°F.). Care should be taken that all of the coats of the vein are divided and that the canula enters the lumen of the vessel and does not make a false passage between its coats. Temporary pressure above helps bring out the vein. The fluid should be allowed to run in slowly about twenty minutes being given to 500 c.c. Too much fluid does harm. The dose is 400 to 700 c.c. for an adult. All the while the effect of the operation should be noted. Intravenous saline infusion is practised when the patient's condition is grave and there is urgency. The infusion may be repeated.

Not a large amount of fluid should be used because it is rapidly eliminated. Adrenalin chloride may be added to the solution.

The apparatus for administering the infusion should consist of the canula connected by a rubber tube to an infusion bottle (Fig. 77). Or the fluid may be allowed to flow into the vein by the force of gravity from an

elevated receptacle as is done in hypodermoclysis (Fig. 194). A funnel or other apparatus may be used. When haste is required, an operative exposure of the vein is not necessary, but a hollow needle may be introduced through the skin into the vein as is done in administering intravenous medication (see Salvarsan, page 291).

The effect of saline infusion is very transient although it may tide over a crisis. It is an emergency expedient. When sterile water can not be had tap water or rain water may be used. Sea water, diluted with twice the amount of fresh water, may be employed.

In *infants*, the *sagittal sinus* is more easily used for intravenous injections than any other vessel. The sinus is best reached about midway between the fontanels. If the sinus is closed, the needle may be inserted at the posterior part of the anterior fontanel. This site may be used for the intravenous injection of sera or other medications. The *external jugular vein* may also be used in infants for the same purpose.

To facilitate the introduction of a needle into the vein for infusion or other medication, J. J. Watson (Jour. Am. Med. Assoc., July 27, 1911) transfixed the dilated vein through its anterior quadrant with a fine sewing needle, passed through the overlying skin and anterior wall of the vein transversely to the axis of the vein. This is lifted forward and the infusion needle introduced just behind the transfixion needle, into the lumen of the vessel (Fig. 196).

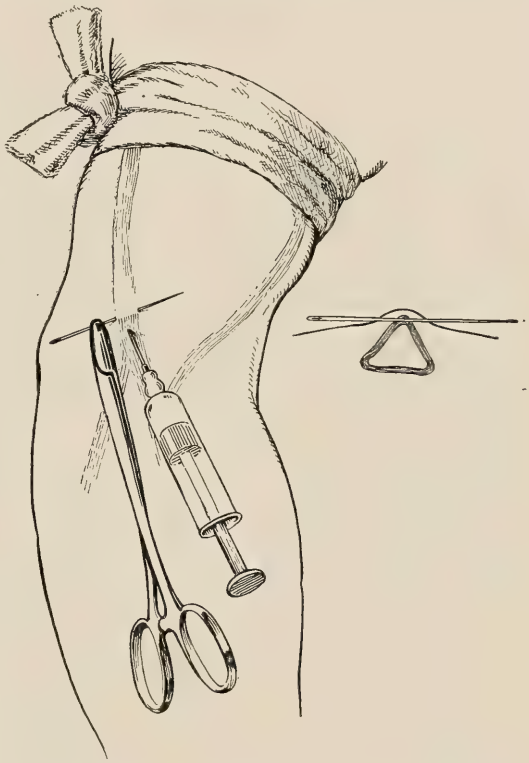


FIG. 196.—TRANSFIXING WALL OF VEIN WITH SEWING NEEDLE TO STEADY IT AND OPEN ITS LUMEN TO RECEIVE THE INFUSION NEEDLE.

The use of *colloidal solutions*, which do not escape from the blood-vessels so rapidly, is useful. J. J. Hogan (Jour. Am. Med. Assoc., Feb. 27, 1915; May 6, 1916) reported experiments with gelatin salt solution and some important clinical successes. Twenty-five Gm. (6½ drams) of pure gelatin, 1.5 Gm. (22 grains) of sodium chloride, and 100 c.c. (3⅓ ounces) of distilled water are boiled for fifteen minutes. The solution is then filtered through heavy paper in a hot funnel into a flask, which is placed in the autoclave and sterilized for an hour at 124°C. (255°F.). It is then cooled in an ice box. If it solidifies it is satisfactory. This is kept in the sealed flask. When needed, the flask of sterile gelatin is warmed until it becomes liquid. It is then added to a sterile solution consisting of 9 Gm. (135 grains) of sodium chloride, 2 Gm. (30 grains) of sodium carbonate crystals, and 1000

c.c. (1 quart) of water which has been warmed to 40°C. (104°F.), and the temperature of the whole kept at that degree while it is being infused into a vein. The infusion of 500 c.c. (1 pint) of this solution should be done just as salt solution is infused. If indicated, 700 c.c. or even 1000 c.c. may be used. It may be given by hypodermoclysis at the rate of 250 c.c. (8 ounces) every three hours. There may be added to the solution used for infusion 5 c.c. of adrenalin solution (1 : 1000) for every 500 c.c. of gelatin solution.

The transient effect of saline solutions may be converted to a permanent effect by adding *gum acacia*. While saline solution increases the blood pressure for a few minutes, it rapidly falls again; but by adding these substances the osmotic pressure of the fluid may be made the same as that of normal blood. Bayliss (Archiv. Med. Belges, lxx, Sep., 1917) found that 2 or 3 per cent. of gum acacia in Ringer's solution possesses a viscosity index similar to that of blood. Gum acacia is not damaged by boiling, and is, therefore, more practical than gelatin.

The use of *sugar infusion* is indicated in the place of salt in many cases. The very sensitive epithelium of the kidneys is injured by too much salt and it is possible that salt solution in cases with diseased kidneys may be decidedly harmful. In infective diseases the kidneys are irritated by the toxins of the disease, and it is possible that saline solutions may add to the irritation. Isotonic solution of grape sugar (4.5 per cent.) should be used. This solution not only does not irritate the kidneys but supplies a certain amount of carbohydrate nourishment. As much as 2 liters of the 4.5 per cent. solution may be used in twenty-four hours. This represents 360 calories. It is possible that sugar will replace salt more and more in infusions. Such injections hasten the elimination of ether after anesthesia. Copious diuresis is promoted.

Patients with deficient urine in infectious diseases, such as typhoid, respond to sugar infusion with free diuresis. For diuretic purposes, hypertonic solution is used. It may be as strong as 10, 20 or even 30 per cent. The injections may be given on alternate days. These solutions by mouth are not as diuretic as plain water. The best diuresis is obtained by transfusion of hypertonic solution, and the ingestion of plain water.

Transfusion is the shunting of the blood current from one person's vessels into the vessels of another. While it is practised in the treatment of shock, infections and blood diseases, its greatest usefulness is in hemorrhage. It is the natural remedy for loss of blood, and the most effective treatment of all the measures employed for acute anemia. This treatment had been tried, and was rejected for many years until perfected by G. W. Crile. The blood should be taken from a donor who is consanguineous to the recipient. Brothers, sisters, parents and children should give their blood to one another. More distant relatives may be used if necessary. The farther apart in family consanguinity the donor and recipient are, the greater is the danger of hemolysis, *i.e.*, the destruction of the red blood cells of one person by the blood of another. In the presence of serious anemia an unrelated donor may be employed. It should preferably be a person of similar complexion type to that of the patient. This operation is not only of use in acute anemia, but has found a large field of application in many constitutional diseases which are characterized by a disordered state of the blood. Pellagra, hemophilia, and leukemia are diseases in which it has been found useful.

Vein-to-vein transfusion does not give current enough unless an artificial pump is introduced. Crile overcame this by connecting an artery of the donor with a vein of the recipient, endothelium to endothelium. The two persons are lain side by side upon two tables, head to foot. Under local

anesthesia the radial artery of the donor is exposed, lifted from its bed, gently clamped in the upper part of the wound with a soft clamp just firmly enough to stop the blood current, ligated in the lower part of the

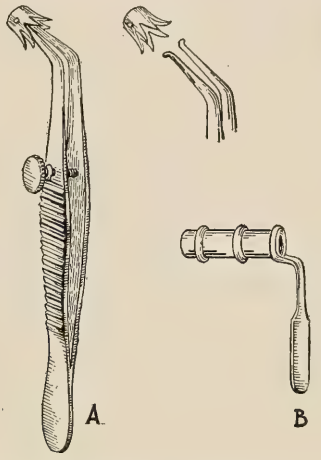


FIG. 197.—*A*, TRANSFUSION COLLAR WHICH DOES NOT REQUIRE LIGATURE. (*Landon.*) *B*, TRANSFUSION COLLAR REQUIRING LIGATURE TO HOLD IT. (*Crile.*)

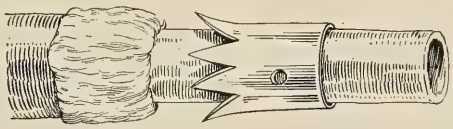


FIG. 198.—DIAGRAM SHOWING TUBE SLIPPED OVER INNER COATS OF END OF ARTERY. The outer coat has been turned back.

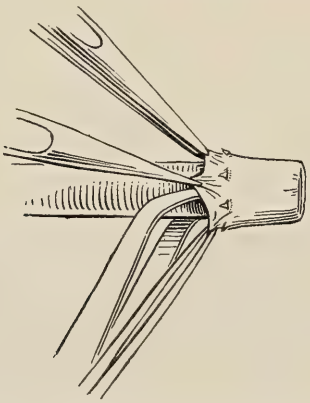


FIG. 199.—END OF INNER COATS OF ARTERY ROLLED BACK OVER TUBE AND CUFF CAUGHT ON POINTS.

wound, and cut above the ligature. With fine anatomic forceps and scissors, the outer coat of the vessel is stripped back at the lower end for a distance of 1.25 cm. (½ inch), care being taken not to injure the inner coats. The end of the vessel is then threaded through a small collar (Fig. 197) made for the

purpose, and, having been passed through the collar is reversed like a cuff, turned inside out, and drawn over the outside of the collar. If the simple smooth tube of Crile is used the cuff must be held by tying a fine thread around it. If the tube with barbs (Soresi) is used the cuff is engaged on the barbs and is thus held (Figs. 198 and 199).

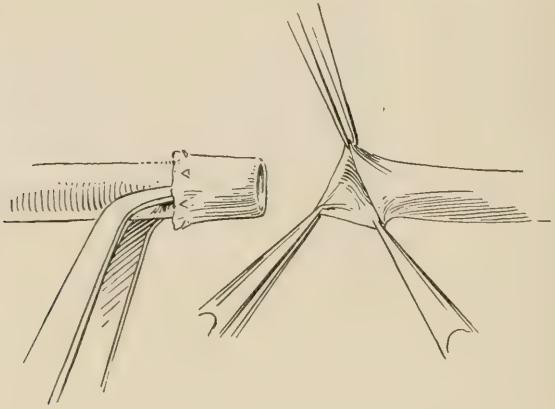


FIG. 200.—CUT END OF VEIN TO BE DRAWN OVER INVERTED INTIMA OF ARTERY.

The median basilic or other prominent vein in the adjacent arm of the patient is exposed under local anesthesia, ligated in the lower part of the wound, occluded with a soft clamp high up, and divided above the ligature. The two arms are then brought together and placed in such position that

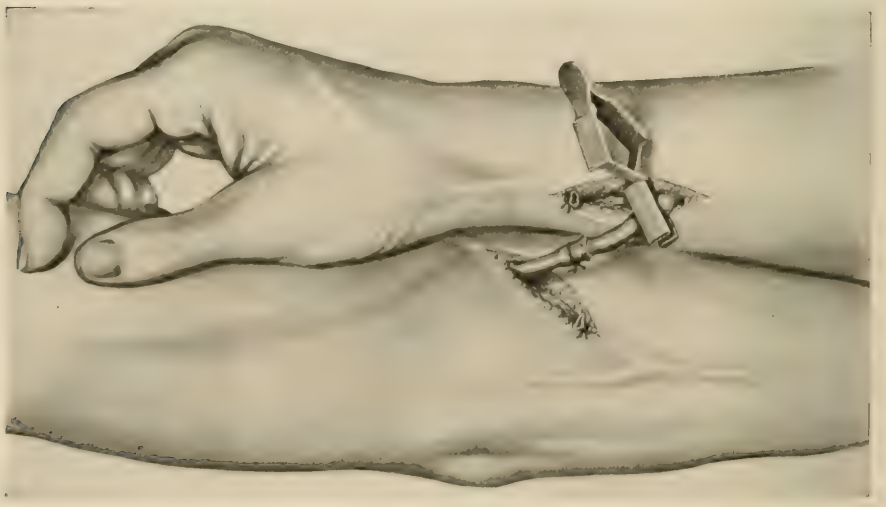


FIG. 201.—TRANSFUSION. UNION COMPLETED.
The result is an intima-to-intima anastomosis. Forceps control the artery.

they lie easily and comfortably side by side, the two wounds being in close juxtaposition. The vein of the recipient is then slipped over the turned-back cuff of the donor's artery (Fig. 200). The vein, artery and collar are all tied together by a stout silk ligature. Just before slipping them together

it is well to relax the occlusive clamps for an instant to see that blood flows. After making the union the clamps are relaxed, and blood flows from the donor to the recipient without coming into contact with any roughness or anything other than the normal lining of blood-vessels (Fig. 201).

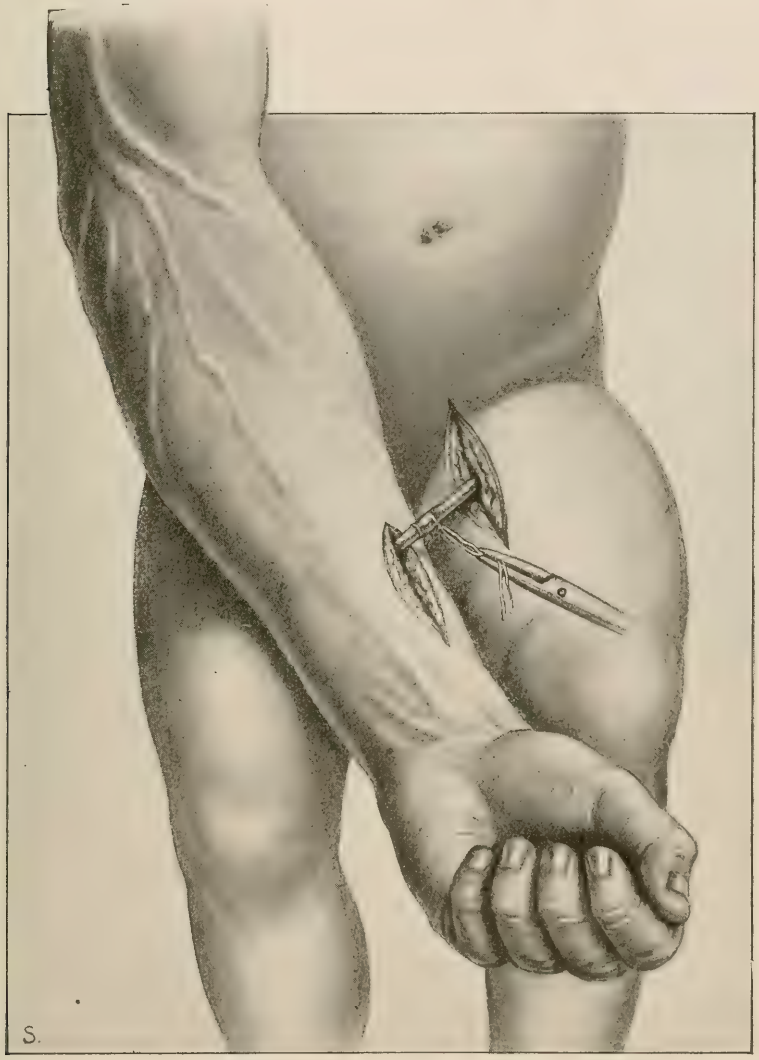


FIG. 202.—TRANSFUSION FROM RADIAL ARTERY OF ADULT DONOR TO FEMORAL VEIN OF BABY.

In practice the arm should be rotated to lie in front of the child's wound. With the two heads in the same direction, the donor's left arm should be united to the child's right thigh, the arm lying on the inner side of the thigh wound. With the child's head at the donor's feet the donor's left arm should lie at the inner side of the wound in the left thigh.

The pulses of the two patients are watched; the one grows slower the other more rapid. The flow of blood is not fast, and half an hour or longer is required to transfer a sufficient amount. It is best that the flow should

not be fast; if it is more rapid than this it should be interrupted slightly by the clamp on the artery. When the circulation of the patient has become sufficiently restored to save life, as evidenced by the pulse, color and general condition, the collar is removed, the vessels are ligated and the wounds closed.

This is a delicate operation. It is not difficult; but to be of service it must be well done. It may be repeated if necessary. The patients may be placed on accurately balanced scales and the weight of blood exchanged measured. At the conclusion of the transfusion the respective vessels are ligated, the tube removed by cutting away the ends beyond the ligatures, and the respective wounds closed with a fine suture.

Many modifications and some improvements upon Crile's instruments have been made. In transfusing infants for hemorrhagic disease of the newborn, the radial artery of the donor is connected with the femoral vein of the child (Fig. 202). In children so exsanguinated as to be pulseless and unconscious, this treatment may be expected to restore life.

The apparatus devised by A. L. Soresi (New York Med. Jour., Apr. 1, 1911) is an improvement on the apparatus of Crile. The cylinders employed are hinged so that they may be placed around the blood-vessels before the vessels are divided (Fig. 203). With all other methods the vessels must be cut as an early step in the operation. With Soresi's apparatus, cutting the vessels is the last step. The cylinders having been placed on the vessels, the wall is picked up with tissue forceps and its tissues hooked over the points on the outside of the cylinder. The vessel is telescoped as occurs in intussusception. In the meantime the blood-current is not stopped. The two persons are then brought together, the vein is cut with a sharp knife about 2 mm. ($\frac{1}{10}$ inch) from the edge of the cylinder. Any part of the circumference of the vein wall which has not been well engaged on the hooks is now picked up with forceps and everted. The open end of the vein is covered with a wet tampon to prevent the entrance of air. The artery, engaged on the cylinder in the same way, is closed by the fingers of an assistant and cut. The everted ends of the blood-vessels are then approximated, as they approach, the assistant releases the pressure on the artery and removes the tampon from the vein. Blood flows forth, the open mouths of the two vessels are pressed together, the bar is screwed firmly, and the anastomosis is complete. The surgeon is cautioned to guard lest blood flow too fast, exsanguinate the donor and cause acute dilatation of the heart in the recipient. This is regulated by making compression on the artery of the former.

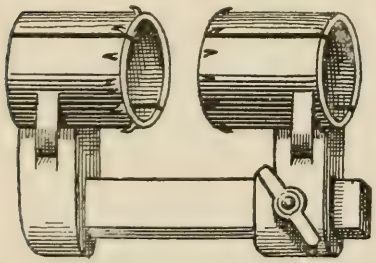


FIG. 203.—TRANSFUSION APPARATUS OF SORESI.

For the open-vessel operations, the self-retaining tubes of L. H. Landon are most effective, and have the advantage of being cheap and simple (Fig. 197*a*).

J. A. Hartwell (Jour. Am. Med. Assoc., Jan. 23, 1909) simplified the operation so that the special instruments may be dispensed with. The artery and vein are dissected out and clamped in the usual manner. The adventitia is removed from each, excepting that a small cuff of it is left curled up on the outside of the artery about 4 cm. (1½ inches) from the

proximal cut end. Three guide sutures of fine silk are passed with a fine needle, 120 degrees apart, in the circumference of the cut end of the vein. The end of the artery is lubricated with sterilized vaselin. The mouth of the vein is held open with the three sutures, and the artery is passed directly into it for a distance of 2.5 cm. (1 inch). One of the guide sutures in the vein is passed through the rolled-up adventitia of the artery, and the excess calibre of the mouth of the vein is closed about the artery with a clamp or a suture, not so tightly as to occlude the artery. The occluding clamps are then removed and the blood-stream allowed to flow. Sauerbruch described this method five years later (Münch. Med. Woch., Nov. 9, 1915).

FIG. 204.—SIMPLE TUBE OF METAL OR GLASS TO CONNECT ARTERY OF DONOR AND VEIN OF RECIPIENT IN TRANSFUSION.

Indirect transfusion means that the blood flows into some other receptacle before entering the patient. This method is now much used and has been perfected since direct transfusion. As the coagulation time of blood is several minutes, blood which is in contact with a foreign substance but a few seconds and then thrown into the volume of circulating blood does not coagulate. For this reason, it has been found that the artery of the donor and the vein of the patient may be connected by a smooth glass or metal tube, and successful transfusion performed (Fig. 204). B. M. Bernheim (Jour. Am. Med. Assoc., May 8, 1915) devised a special clamp to hold the tubes, so that a ligature is not required (Fig. 205).

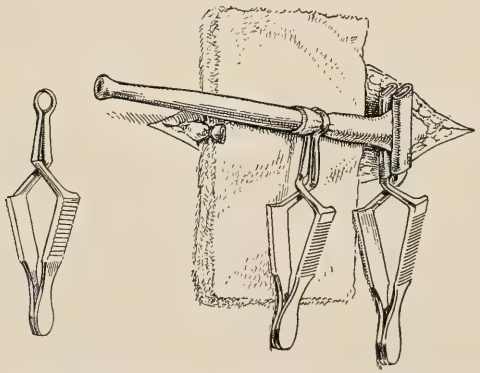


FIG. 205.—SPECIAL CLAMP OF BERNHEIM TO HOLD WALL OF VESSEL TO THE TRANSFUSION TUBE AND OBVIATE NECESSITY FOR LIGATURE.

E. Lindeman (Am. Jour. Dis. Child., July, 1913) inserted a special canula needle into the vein of the recipient and donor, without incision of the skin. Blood is drawn from the vein of the donor with a syringe; the syringe is disconnected from the canula, and connected to that of the recipient. A number of syringes are kept going. No syringe is used a second time until thoroughly cleansed. One syringe is filled while another is being emptied. One operator fills the syringes, another empties them. A little saline is injected occasionally to prevent the formation of a clot in the canula. From six to twelve seconds are required to fill and empty a syringe.

L. J. Unger (Jour. Am. Med. Assoc., Feb. 13, 1915) devised a special syringe for this purpose. By means of a four-current cock, the syringe may be made to operate either way upon donor or recipient, and eject or aspirate either blood or saline, together or alternately. Without making any disconnection, one operator may aspirate blood from the donor, inject it into the patient, inject saline into the donor or patient if desired, and keep the apparatus washed out with saline.

B. Vincent (Surg., Gyn. and Obst., Nov., 1916) devised a simple glass receptacle with a needle attachment, and coated needle and tubes with paraffin to prevent coagulation. The tube is a glass cylinder holding 300 c.c.

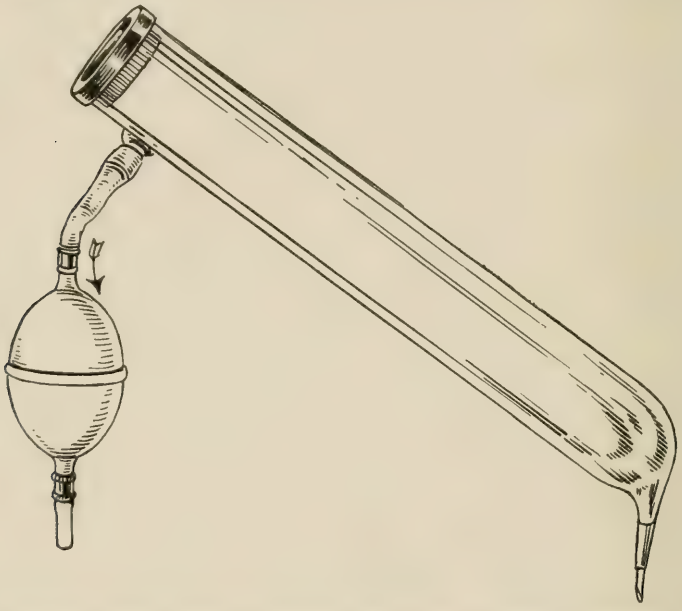


FIG. 206.—SIMPLE GLASS TUBE OF VINCENT INTO WHICH BLOOD IS RECEIVED FROM THE DONOR AND INJECTED IMMEDIATELY INTO RECIPIENT.
For injecting, the rubber bulb pump is taken off and reversed,

The upper end is closed with a rubber stopper. A side opening admits air from a rubber bulb. The lower end has a ground-glass joint which fits into the needle (Fig. 206). The inside of the tube and needle are coated with melted paraffin before the tube is used. The disadvantage of apparatus is that a glass-metal connection breaks easily, although for administering the blood, the glass tip may be inserted into the exposed and incised vein without the use of the needle.

B. M. Bernheim (Jour. Am. Med. Assoc., Oct. 9, 1915) devised a simple apparatus consisting of a U-tube, connected to a syringe, whereby blood is sucked from a vein or artery of the donor, and a shuttle-cock turned and the blood injected immediately into the recipient (Fig. 207).

Such methods as these described above have the advantage that the *amount of blood* may be accurately measured. The amount of blood which may be taken from a donor at one sitting varies from 500 to 1400 c.c. From 800 to 1000 c.c. may be taken from a large healthy person at one operation. It is best not to ask for more than 600 or 800 c.c. from any individual. Several transfusions may be made at intervals. The same or another donor

may be used. The donor makes blood surprisingly fast. The patient may be given at a sitting from 500 to 2000 c.c. When as large an amount as the latter is given it must come from two donors.

The total amount of blood in the body is about one-nineteenth ($\frac{1}{19}$) of the body weight. It is safe to take one-fourth of the donor's blood; in some cases as much as one-third can be given. Libman and Ottenberg (Jour. Am. Med. Assoc., Mar. 7, 1914) worked out a formula, based upon the percentage of hemoglobin, whereby the amount of blood received and lost may be calculated.

For taking blood from the donor the puncture of a large vein of the arm with a needle is most simple. The recipient may be given the blood by a needle puncture in a vein, but it is usually better to expose the vein by incision. In giving blood to infants, with an open anterior fontanelle, the needle may be inserted directly into the superior longitudinal sinus as suggested by H. F. Helmholz (Am. Jour. Obst., Sept., 1915).

The occurrence of *hemolysis* or *agglutination* in transfusion may be avoided by testing the reaction of one blood to another before the transfusion is performed. When the blood of a person not intimately connected with the patient, biologically or socially, is used the tests for syphilis and tuberculosis should be made if time permit. The tests for agglutination should be made if possible in all cases, as even among the nearest of kin hemolysis is possible. Perhaps the only guarantee against it is when the mother's blood is given to the newborn.

The *technic of agglutination tests* as given by Sydenstricker, Mason and Rivers (Jour. Am. Med. Assoc., June 9, 1917) is as follows:

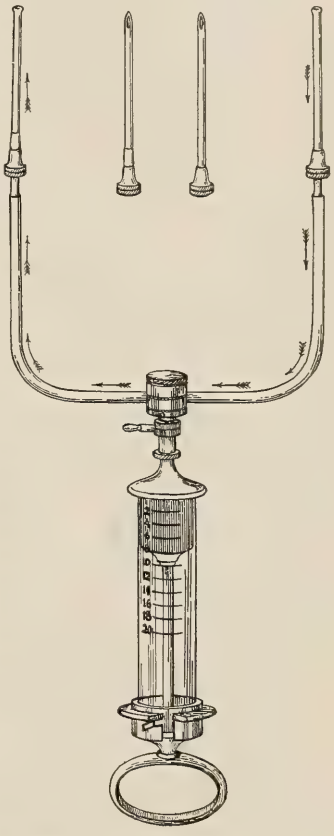


FIG. 207.—SIMPLE SYRINGE APPARATUS OF BERNHEIM, CONNECTED WITH U-TUBE, WHEREBY BLOOD MAY BE ASPIRATED FROM VEIN OF DONOR AND INJECTED INTO VEIN OF RECIPIENT WHILE THE TWO ARE CONNECTED.

Either needles or blunt tubes may be used.

Blood is drawn from donor into a small test-tube and centrifuged to obtain clear serum. Two drops of blood are drawn from the finger or ear of patient into 5 c.c. of 1.25 per cent. sodium citrate in 0.85 per cent. salt solution to obtain a suspension of corpuscles. A citrate solution is used to prevent clumping of the cells in the cases in which several drops of blood are required to make a satisfactory corpuscular suspension. A cover slip is cleaned with 95 per cent. alcohol, and by means of capillary pipets (one for each serum and each corpuscle suspension) 1 drop of donor's serum and 1 drop of recipient's corpuscles are placed on it and stirred with a small glass rod. This is inverted over a hollow ground slide and sealed with oil. The hanging drop should now be examined under the microscope. It is of the utmost importance to have the drop spread out to an even thickness, with the corpuscles just touching one another. The process should be repeated, donor's corpuscles and recipient's serum being used. Controls may be made with salt solution instead of serum, but are not necessary except in doubtful cases. It is unnecessary to wash the corpuscles used in performing agglutination tests, as the amount of serum present in the emulsion is too small to cause confusion.

The hanging drops should be allowed to incubate at 37°C. for one hour before hemolysis or agglutination can be excluded. Many reactions would be avoided if this rule were

strictly followed. Several instances in which agglutination and hemolysis were absent at the end of thirty minutes have shown agglutination at the end of forty-five minutes. Previous to the observance of this rule, reactions following several transfusions, were explained when the bloods were subsequently tested, showing no agglutination in thirty minutes but definite incompatibility at the end of forty-five minutes. Agglutination is often present at the end of five to ten minutes, however, occasionally with complete hemolysis at the end of thirty minutes.

Sodium citrate in indirect transfusion is used in 0.2 or 0.25 per cent. solution. This salt has the power of preventing coagulation, and when added to the drawn blood, greatly lessens the danger of thrombosis. The former use of 1 per cent. strength proved that the drug is toxic in such high concentration. An adult may tolerate a total dosage of about 5 Gm. (75 grains) of the drug. Thus in 0.2 per cent. solution, 2500 c.c. of blood may be transfused which is more than is commonly used.

R. Lewisohn (Annals of Surg., Nov., 1916) found that if one mixes sodium citrate with blood in the proportion of 0.1 per cent. the blood clots just as quickly as non-citrated blood; but if the proportion is increased to 0.15 per cent. (0.15 Gm. of citrate to 100 c.c. of blood) the mixture will remain fluid for two days. This seems to be the minimum amount; and therefore to prevent error 0.05 per cent. is added to bring the amount up to 0.2 per cent. To get a 0.2 per cent. solution, 180 c.c. of blood is drawn from the donor, and mixed with 20 c.c. of a 2 per cent. stock solution of sodium citrate. As soon as this percentage is thrown into the circulation of the recipient the dilution becomes so great that coagulability is not effected. The advantage of the citrate is that coagulation need not be feared in the apparatus, and with this method it is possible to carry the blood a long distance to the recipient.

The technic of the citrate method is simple. The tourniquet is applied to the donor's arm and one of the large veins at the elbow, preferably the median cephalic, is punctured with a trocar and canula or large hollow needle. The blood should be collected in a warmed graduated glass jar containing a 2 per cent. solution of sodium citrate. If it is intended to give an infusion of 500 c.c. of fluid, 450 c.c. of bood are allowed to mix with 50 c.c. of the 2 per cent. solution. This gives a 0.2 per cent. citrate mixture or 2 to 1000. A weaker solution than this will coagulate.

The technic of infusion usually requires that the vein of the recipient be exposed by a small incision because of its flatness. The apparatus used for the administration of intravenous medication in syphilis may be employed. The canula is inserted in the vein and the fluid allowed to flow in by gravity. The rubber tube and the bottom of the receptacle should previously have been filled with normal salt solution. The whole operation can be done with glass funnel, a short piece of rubber tubing, a hollow needle and some sodium citrate and water.

Conclusions Concerning Transfusion.—The most simple, useful and effective method of transfusion is the citrate method. The blood from the donor is drawn by puncturing the vein, without incision, by means of a hollow needle. The blood is allowed to flow into a measuring glass containing citrate solution. The only apparatus thus far is a hollow needle and a receptacle. A vein of the patient, without incision, is then punctured with a hollow needle. The blood, mixed by stirring with a glass rod, is poured into the ordinary gravity salvarsan apparatus, the rubber tube is connected with the needle in the patient's vein and the fluid allowed to flow into the patient.

Transfusion of blood is more effective in hemorrhage and shock than is infusion of watery solutions.

When to transfuse is often a doubtful question. No rules can be given.

A sudden loss of blood is much more serious than a gradual loss to the same degree of anemia. Pallor, the cold skin, anxious countenance, rapid pulse, air hunger, low blood-pressure, thirst and small pulse are all signs which point to the need of transfusion. When the blood-pressure falls as low as 75 mm. of mercury, with the above signs present, transfusion is strongly indicated. Death is apt to occur when the blood-pressure falls below 70 mm.

If infusion of salt solution has not restored blood-pressure transfusion is called for. There is no use in waterlogging a patient with salt solution when he needs blood. It is possible to do damage by overfilling the vessels and overdiluting the blood with water. It runs out very fast. If 1000 or 1500 c.c. of salt solution do no good, it may be assumed that a repetition of the dose will not, and transfusion is indicated.

If time and apparatus permit, it is best to use for transfusion a needle of 10 to 14 gage, preferably of platinum iridium or nickel alloy, connected by a short rubber tube to a closed bottle. The neck of the bottle should be closed with a stopper having three perforations. Right-angle glass tubes should fit the side holes. One should connect with the short tube to the needle. The middle hole should accommodate a graduated glass funnel provided with a cock. The other side tube should connect with a rubber tube containing a glass trap filled with cotton, through which suction may be made if necessary to promote the flow of blood. All of this apparatus should be sterilized in the autoclave or by boiling. Five cubic centimeters of the citrate solution are run into the bottle. A bandage or rubber tourniquet is placed about the donor's arm above the elbow. It should not be so tight as to compress the artery. The skin in front of the elbow should be cleansed and the needle caused to pierce a large subcutaneous vein. Usually the blood flows freely. Rarely will suction to produce negative pressure in the bottle be required. As the blood flows into the bottle the cock is opened slightly and citrate solution from the funnel allowed to enter the bottle and mix with the blood at the rate of 10 c.c. for each 90 c.c. of blood. The bottle should be agitated gently to facilitate the mixture.

The blood mixture may be poured into a salvarsan gravity tube. This vessel should have been sterilized and rinsed with salt solution. From this the blood is allowed to flow into the patient's median basilic vein after the manner of administering salvarsan. The fluid should be allowed to flow into the patient at the rate of about 500 c.c. in twenty minutes.

When agglutination tests can not be made or when incompatible blood must be used, washed corpuscles may be employed. This means removal of the plasma. The blood is drawn as usual and mixed with citrate. The blood is placed in 100-c.c. centrifuge tubes which have been sterilized and rinsed with salt solution. The tubes are covered with caps and centrifuged at 2500 revolutions for fifteen minutes. The supernatant plasma is then piped off and 0.8 per cent. sodium chloride solution added to the corpuscular residue to bring the total volume up to the original amount. This fluid is then administered the same as usual.

Intravenous injection of oxygen was successfully accomplished by F. W. Tunnicliffe and G. F. Stebbing (Lancet, Aug. 19, 1916). They showed that oxygen could be introduced into the veins in quantities from 500 to 1000 c.c. at the rate of 600 to 1200 c.c. per hour. The injection should at first be at the rate of 500 c.c. per hour. The gas is injected for periods of from ten to fifteen minutes with intervals of two or three minutes between. During the intervals a little gas should continue to flow to prevent clotting in the needle. A needle such as is used for injecting salvarsan is connected by a rubber tubing with the gasometer or rubber bag through which the filtered gas is passed.

This treatment is indicated in cases of cyanosis in which the heart is not diseased. Cases of cyanosis and dyspnea due to respiratory disorder are most amenable to this treatment. Cases in which the inhalation of oxygen would be indicated, but in which for some reason it can not be given by inhalation, may thus be infused.

The cyanosis rapidly disappears. The more cyanosed the patient the more rapidly is oxygen absorbed and the more rapidly may it be given. As the cyanosis diminishes the rate of flow of the gas should be diminished. The pulse should be constantly watched, and the heart constantly listened to with the stethoscope. Irregularity in a previously regular pulse or increased irregularity in a previously irregular pulse is an indication that the flow of gas should be discontinued.

Interstitial injections of oxygen may be made in the same conditions as intravenous injections. The needle is introduced into the connective tissue of the chest or suprapubic region. The absorption of the oxygen is not quite so rapid as when injected into the blood, but rapid enough to be appropriated eagerly by the hungry red blood cells.

Reactionary Hemorrhage.—When bleeding vessels have become occluded by clot, as the patient makes more blood and the heart becomes stronger and the intravascular pressure increases, the coagulated blood may be forced from the mouths of the vessels, and hemorrhage may recur. Poorly tied ligatures may give way under the reaction. For this reason we can not always be sure that hemorrhage is permanently controlled until reaction has taken place, because the hemorrhage was staunched under low-pressure conditions. Reactionary hemorrhage is prevented by good primary control of bleeding points, and by a not too vigorous application of blood-pressure-raising treatment. If bleeding has been thoroughly stopped and the patient is still alive, if he has much vitality, he will generally recover. Too much haste in whipping up the circulation can often do more harm than good. The administration of strychnin, digitalis and the long catalog of drugs, once in vogue in treating the exhausted nervous system, has fallen into disuse. The danger of too rapidly increasing the blood-pressure should be guarded against especially after internal and hidden hemorrhage.

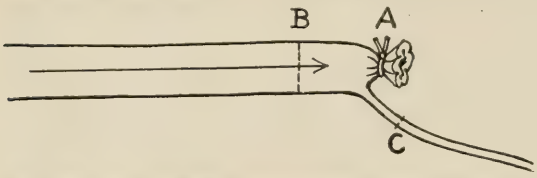


FIG. 208.—*A*, SHOWING LIGATURE OF ARTERY APPLIED TOO CLOSE TO FIRST LARGE BRANCH ABOVE. It would be better to ligate at *B* or at *A* and *C*.

Secondary Hemorrhage.—Hemorrhage coming on two days or more after the vessels were closed and after reaction has taken place should be treated the same as primary bleeding. What is more important than its treatment is its prevention. It is prevented by attention to *constitutional diseases*, such as septicemia, pyemia, syphilis and nephritis. Diseases of the arteries should be given consideration. In ligating *atheromatous vessels* large ligatures should be used and tied not too tightly. *Proximity to branches* should also be considered: thus if a vessel is tied and cut, or cut and tied, too closely to the first large branch above, not sufficient room is left for the formation of a good-sized clot, and when the ligature softens the clot may be forced out. It is better under such circumstances to ligate higher or to ligate the branch also (Fig. 208). *Infection* in the wound is the most prolific cause of secondary hemorrhage, on account of which, efforts to maintain asepsis in wounds in which large vessels are ligated are of extraordinary

importance. *Ulceration* and *sloughing* in such wounds is apt to lead to bleeding; and in the days of hospital gangrene, secondary hemorrhage from this cause was common. *Defective tying* of ligatures, *premature softening* of ligatures, the development of *high blood-pressure*, and bleeding from the *distal side* of the artery also contribute to cause this accident, and must be guarded against.

Hemorrhage in Special Conditions.—There are certain diseases in which hemorrhage is more prone to occur. Most of them are preventable, but when they have developed, their hemorrhagic tendencies demand the consideration of the surgeon.

Hemophilia is one of the surgical perplexities. A person known to have this disease should be protected from wounds and should be subjected to operation only as an extreme resort. Children should be closely guarded. It is not the bleeding from large vessels that gives the most trouble, large vessels can be ligated; but capillary oozing is checked with the most difficulty. Sometimes it seems impossible to control it. The local use of astringents seems unavailing. The cautery is of but slight service as hemorrhage continues under the burned tissue and lifts it up. *Pressure* is the most effective treatment. Its value is increased if combined with heat. It is best applied by placing next to the wound some smooth rubber tissue, and packing gauze upon it. If gauze is applied against the bleeding surface, and coagulation is secured, the clot which plugs the mouths of the vessels becomes engaged in the meshes of the gauze and when it is removed the clots are pulled out. Pressure must be firm and continuous, but not to the degree of causing necrosis, lest a worse condition than the first be created. The pressure must often be continued for several days. Gelatin locally may be of service. It is probable that the vessels are not closed by clot but by the surfaces of the vessels becoming adherent. It is doubtful if the internal use of gelatin or calcium salts is of service in this disease. Elevation of the part and restriction of fluids are helpful. The transfusion of blood, from a close kinsman, is the most effective treatment. In lieu of this, blood-serum injections are useful. The permanent cure of hemophilia may be accomplished by the repeated withdrawal of small quantities of the patient's blood and the injection of fresh normal human blood-serum. Thyroid extract is said to be of curative value.

Infection in the tissues, because of its tendency to produce septic thrombosis and secondary hemorrhage, should prompt the surgeon to avoid, if possible, exposing large vessels through such tissue. Thus in amputating for sepsis it is often more practical to ligate the main vessels above the field of amputation. I have in mind two cases of infection of the thigh and adjacent tissues requiring amputation to save life. In one the typical operation was done and the vessels tied in the wound; in the other an aseptic, preliminary ligation of the femoral was done just below Poupart's ligament. The latter was the better surgery. In ligating vessels of some size in wounds which are to become infected chromic catgut should be used in preference to plain gut, and every provision for good drainage should be made. The infection should be treated.

Local congestion or venous obstruction tends to increase hemorrhage in a wound in tissues so affected. Any condition causing hyperemia, such as tumor, displaced bone fragments, or embolism should be looked to. Constricting bandage or angulation of a joint are hyperemia-producing conditions which may aggravate hemorrhage.

Jaundice, complicated by hemorrhage, requires treatment similar to that of hemophilia. There is a decrease in the coagulability of the blood.

Large vessels can be ligated and the approximated internal surfaces adhere, but capillaries are best controlled by pressure. *Calcium* increases the coagulability of the blood, and if given for two or three days before operation in jaundiced patients may be of service. The cause of the jaundice should be treated.

Purpura, giving rise to hemorrhage, is combated by the treatment of the causative factor. Hemorrhages occurring under the skin or in the connective tissue should be left to become absorbed. If the clot becomes infected the cavity made by the blood should be opened, cleaned out and drained. If bleeding is still present the cavity should be packed with gauze. In the event of a hemorrhagic focus being discovered while the bleeding is going on cold or pressure should be applied to check the hemorrhage. Large collections of blood are best treated by aseptic evacuation if they produce undesirable pressure or swelling or are apt to become infected.

Treatment by blood and serum infusions is the most effective. Subcutaneous or intravenous infusions of human blood-serum are useful. Transfusion of human blood is most effective. Before transfusion is done, the simple injection of whole fresh human blood into the gluteal muscles should be tried. Such an injection may be at the rate of 1 c.c. of blood for every 1 kilo (2 pounds) of weight. A child weighing 40 pounds would be given 20 c.c.

Scurvy causes multiple hemorrhages which should be treated by treating the scurvy (see page 321) and by the local and general methods which apply to purpura.

Leukemia, causing hemorrhages, is treated by combating the leukemia and by applying to the hemorrhages the same treatment as is applied to purpura.

Pernicious anemia, complicated by hemorrhages, requires the same local treatment as the above condition. Blood or serum infusions are useful.

Traumatic asphyxia, causing a hemorrhagic condition in the head, neck and thorax, is best met by giving the patient abundant fresh air and allowing him to sit propped up in the upright position.

Compression of Special Arteries.—In wounds of arteries, in amputations and in emergencies to check bleeding, compression of the main trunk of the artery is called for. It is often difficult to compress an artery without compressing the accompanying vein, but if possible the artery alone should be compressed. A knowledge of the course of the vessels is important. The large arteries may be located by their pulsation.

The *carotid arteries* may be compressed by digital pressure toward the muscles lying in front of the transverse processes (Fig. 209). To compress the *subclavian*, the fingers or a small block are pressed behind the clavicle engaging the artery against the outer surface of the first rib. The shoulder should be depressed, and the direction of the pressure should be downward, backward and inward (Fig. 210). The *brachial artery* lies close to the humerus, against which it can be compressed in the upper part of its course by pressure from within outward (Fig. 211) and in the lower part by pressure backward. Extreme flexion at the elbow also compresses it (Fig. 212).

The *abdominal aorta* can be compressed anywhere below the ensiform process. Pressure may be made by standing in an elevated position at the left side of the patient, and, with the arm straight, throwing the weight of the body against the aorta through the fist applied slightly to the left of the umbilicus, the posterior surfaces of the last four proximal phalanges being well adapted for compressing the vessel against the spinal column and it muscles (Fig. 213).

FIG. 209.—DIGITAL COMPRESSION OF CAROTID ARTERY.

FIG. 210.—DIGITAL COMPRESSION OF SUBCLAVIAN ARTERY.

FIG. 211.—DIGITAL COMPRESSION OF BRACHIAL ARTERY.

FIG. 212.—COMPRESSION OF BRACHIAL ARTERY BY FORCED FLEXION OF ELBOW.

Compression of the abdominal aorta by *belt constriction*, popularized by Momburg, is accomplished by applying tightly about the body, between the last rib and the crest of the ilium, a heavy rubber elastic tube (Fig. 214). The tubing should have a diameter of nearly 2.5 cm. (1 inch). It should be 1½ to 2 meters long. In emergency, the tube from a gas stove may be used. It should be drawn tightly enough to stop pulsation of the femoral artery below Poupart's ligament. This requires two to four turns. After each turn the femoral pulse should be tested. Muscular and heavy persons

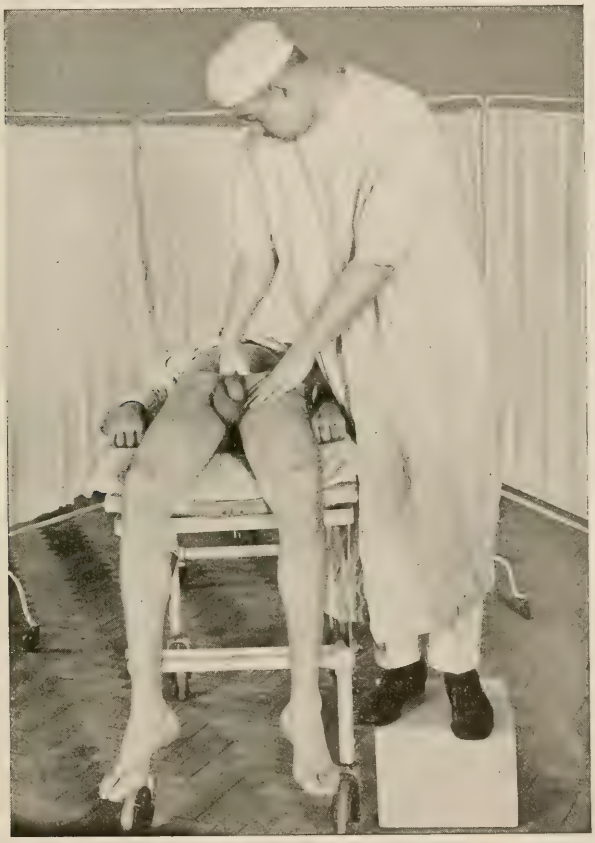


FIG. 213.—MANUAL COMPRESSION OF THE ABDOMINAL AORTA.

require more turns than the thin and flabby. Instead of pulling harder on the tube, it had better be wound around more times to get the desired result. No more turns than are enough to suppress the pulse in the femoral artery should be taken. Relaxation with a general anesthetic is desirable, although it is used in obstetrics in many cases without an anesthetic. A little morphin may be employed. The chief cause of failure is in not having the belt tight enough. It may be used quickly as an emergency expedient in pelvic hemorrhage without any other bandages being used. It is well to elevate the pelvis, or by massage to crowd the intestines toward the diaphragm before applying the belt.

In moderate anemia, to get the best results, the blood should first be expelled from the lower extremities by elevating them and applying a rubber bandage from the toes to the groins. The abdominal constriction is then applied. Following this the bandages are immediately removed from the legs, and the legs are allowed to hang down. The blood from the pelvis thus flows down into the empty vessels of the legs, and pelvic hemostasis and anemia are complete. If the patient has not lost much blood, the blood should not be expelled from the legs and driven into the body as the burden

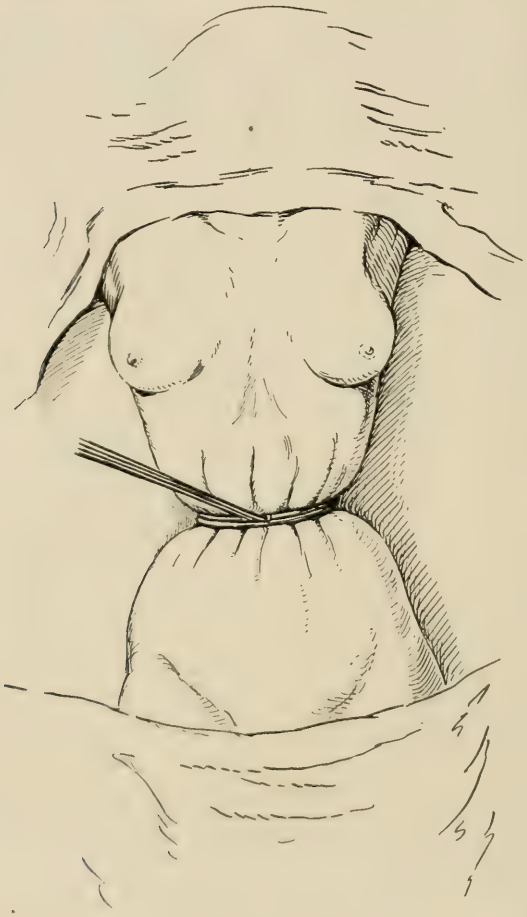


FIG. 214.—BELT CONSTRICTION OF THE AORTA.

thrown upon the heart may be too great; but the legs and the thighs should have the tourniquets placed about them as they lie horizontally, thus leaving the normal amount of blood in the lower extremities, and not throwing an extra burden upon the heart.

The successful application of this method requires that there shall be nearly normal elasticity of the heart and vessels, as the burden thrown upon the circulation above the compression is very great. Blood-pressure is increased and respiration becomes rapid. It cannot well be used in arteriosclerosis or valvular disease of the heart. In severe anemia it seems to be

dangerous. If the heart yields to the blood-pressure and becomes dilated, serious collapse occurs. The constriction may be left on for thirty or forty minutes.

Momburg (Archiv. für klin. Chir., lxxxix, No. 4, 1909) reported a case in which the constriction was left on for two hours and twenty minutes without apparent deleterious results. If the patient is not doing well it must be removed. The intestines and ureters are not often damaged by it. Before removing the belt, it is well to apply constriction around the upper part of the thighs and also below the knees so that the blood from the body

FIG. 215.—DIGITAL COMPRESSION OF FEMORAL ARTERY.

does not suddenly rush into the legs and reduce blood-pressure too rapidly. The thighs should be elevated and the abdominal constriction should be removed gradually; as should also the thigh constrictions and the leg constrictions.

In postpartum hemorrhage this method gives brilliant results. In operations on the rectum and other pelvic organs it has been used with much less satisfaction than in post-partum hemorrhage. In operations for disarticulation of the thigh at the hip-joint the method has worked well. In several hundred cases no serious results have followed its use; but fatal gangrene of the intestine has been reported. Ulcer of the intestine may be a cause of such mishap.

D. Gelyi (Mediz. Klinik, Aug. 28, 1910) perfected an apparatus whereby a steel and rubber pad is screwed down upon the region of the abdominal

aorta. This is connected to a standard fastened to the operating table. Pressure is brought directly upon the aorta without constricting the rest of the abdomen. C. J. Gauss (Zentralb. für Gynakol. May 4, 1912) invented an *artery press* which works on the principle of a letter press. A broad metal plate fits behind the back, which conforms to the curve of the lumbar region.

FIG. 216.—COMPRESSION OF FEMORAL ARTERY BY FORCED FLEXION OF THIGH.

FIG. 217.—COMPRESSION OF LOWER FEMORAL AND POPLITEAL ARTERIES BY FORCED FLEXION OF KNEE.

A plate is screwed laterally on either side to hold the patient immovable. An elastic pad screws down in front upon the abdominal aorta at the exact place where pressure is needed. These more accurate means of applying pressure to the abdominal aorta are destined to supplant the use of the elastic belt excepting as an emergency expedient.

It is possible to compress the *internal iliac artery* in a lean person by making pressure through the abdominal wall, backward, upward and outward, against the brim of the pelvic canal. This also compresses the ureter. Digital compression may be made directly upon the vessel through a small abdominal opening. The *external iliac* is compressed just above Poupart's ligament, under which it passes midway between the anterior-superior spine of the ilium and the symphysis of the pubes. The *femoral artery* may be compressed effectively just below Poupart's ligament (Fig. 215) or by forced flexion (Fig. 216). A pad in the popliteal space and forced flexion of the knee, the leg being bandaged to the thigh, compresses the lower femoral and *popliteal artery* (Fig. 217).

Constriction of Limb for the Control of Bleeding.—Preceding amputations, in some operations on the extremities, in some wounds of large vessels, and in some operations on vessels, the whole limb may be constricted temporarily to shut off the circulation.

FIG. 218.—RUBBER BANDAGE APPLIED.
The part of the bandage which has not been unrolled is slipped under the upper turns and compresses the vessels.

Artificial local anemia is secured by expelling the blood from the limb. For this purpose the rubber bandage of Esmarch is used. This bandage for the leg and thigh should be about 10 cm. (4 inches) wide and 5 to 7 meters (5 to 7 yards) long. After holding up the limb vertically for several minutes, to let the blood flow out of it, the bandage should be started at the tips of the toes or fingers and continued spirally up to the place where constriction is to be made. The bandage should be drawn tightly and each turn should just meet or very slightly overlap the preceding turn. If an operation or amputation is to be done for infective disease, the bandage should be carried only as far as the disease, then another bandage should be begun just above the disease, lest infective material be pressed into the circulation. This bandage squeezes the blood out of the limb into the trunk and helps fill the other vessels. At a point, far enough above the field of operation to be out of the way, constriction is made to prevent blood returning into the limb. This constriction in the arm and leg may be made by taking a number of turns with the rubber bandage and fixing the end by tying it with tapes or by slipping it under the previous turns. This having been done, a firm pad of gauze (nothing is better than a roll of gauze bandage) is slipped under the constricting bandage in such a position that it presses directly upon the main artery of the limb (Fig. 218).

In the thigh, a tourniquet should be used for the final constriction. This may be used also in the leg and arm too, if desired. For a tourniquet a heavy piece of rubber tubing is used, drawn tightly and caught with heavy clamps or a hook or tape. The old-fashioned tourniquet is useful but has been superseded by the more simple device.

The constricting tourniquet having been applied, the rubber bandage is removed from the rest of the limb. It is removed from below upward. This

FIG. 219.—EXPULSION OF BLOOD FROM LIMB BY GRAVITY AND APPLICATION OF RUBBER ELASTIC CONSTRICTOR.

is easily accomplished if the turns have not been made to overlap too much. This leaves the limb pale and almost bloodless. If the compression has been applied skillfully the amount of blood left in the limb is very small.

The tourniquet or final constriction above the seat of operation should be at some level at which the vessels may properly be compressed. The final constriction should not be applied over the leg or forearm because the vessels lie protected between the two bones and the constricting band will fail to compress them. The best place for constriction in the leg or arm is

about the femur or humerus. The constriction should not be so tight as to damage the vessels or nerve trunks lest the limb be permanently paralyzed.

A limb enveloped in a rubber compressing bandage should not be flexed or extended suddenly lest the restricted tissues be torn. The constriction should be left on only the shortest possible time necessary to perform the operation. Constriction of longer than an hour or an hour and a half is apt to be followed by fibrous necrosis of the muscles or gangrene. The aged are particularly susceptible to such damage. Half an hour of constriction may be followed by gangrene in the arteriosclerotic. Healthy persons may tolerate two or three hours of constriction without damage.

Gravity ischemia with elastic constriction may be used without forcing the blood from the limb with the rubber bandage. Less damage is done to the tissues by this method, and it is to be preferred in debilitated patients. The limb is held in the perpendicular position until the blood flows out by gravity.

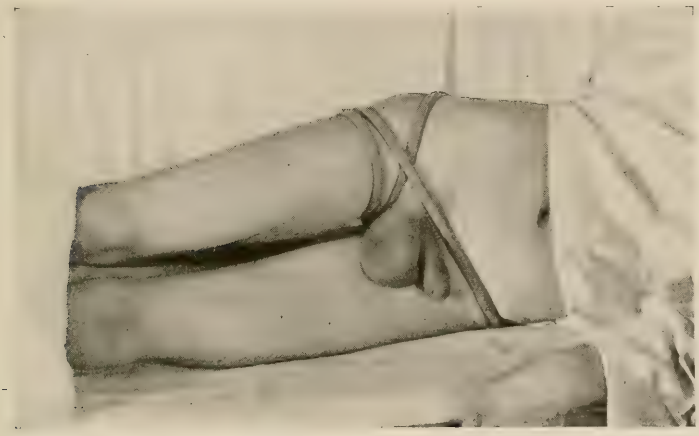


FIG. 220.—SHOWING RUBBER TUBING CONSTRICTOR APPLIED TO HIP.
A roll of bandage may be placed under the constrictor at groin and compression of the external iliac artery secured.

This may be facilitated by stroking it strongly with the hands toward the trunk. The elastic constrictor is then applied at the root of the limb or at the thigh or arm above the seat of operation (Fig. 219). At the groin the constriction may be carried above the pelvis (Fig. 220).

The *sequestration of blood*, by compression of vessels for operative purposes, makes use of the fact that veins are more easily closed by pressure than are arteries. By compressing the main veins of the extremities close to the trunk a large part of the total blood of the body may be confined in the limbs. For operations on the trunk, neck and head, this procedure greatly reduces the bloodiness of the field of operation. From an anesthetic standpoint, it permits flooding the system with unanesthetized blood after the operation, with the result of a quicker recovery. About one-fourth of the total blood may thus be sequestered: that means that, 1300 to 1500 c.c. of blood is confined in the limbs. Blood-pressure is lowered and respiration and pulse-rates are increased. Morphin and scopolamin may be given as a preliminary to prevent pain. The limbs are allowed to hang below the trunk and elastic constriction is applied to both arms and thighs forty-five or sixty minutes before the operation, tightly enough to stop the venous return,

overcoming the diastolic pressure, but not shutting off the arterial circulation. This may be continued throughout the operation or the constriction may be tightened after the limbs are filled with blood. In most cases it will be observed that the bleeding during the operation is decidedly lessened.

The use of *local compression* is desirable to diminish or prevent bleeding in operations. This is the principle employed when the tourniquet is used to exclude the blood from an extremity. The tight elastic band about the head, to prevent bleeding in operations on the scalp, is described elsewhere (Vol. II). F. P. Corrigan (Jour. Am. Med. Assoc., July 17, 1915) devised a ring, made of pliable lead composition, which may be pressed down upon the scalp or other region, and held by an assistant or by a rubber bandage (Fig. 221). This ring not only may be made to compress the vessels and produce anemia, but also to retain the local anesthetic within a confined area. It is useful for superficial operations.

FIG. 221.—RING COMPRESSION FOR PRODUCING TEMPORARY HEMOSTASIS IN A LIMITED AREA.

General Rules and Suggestions for the Treatment of Hemorrhage.—Hemorrhage from small superficial wounds requires local aseptic compression. In applying pressure above a wound it should be remembered that while compression of the artery tends to check bleeding, pressure upon the vein tends to increase it. When a large artery is opened by a puncture or bullet wound, it is best temporarily to control hemorrhage by pressure, enlarge the wound and tie the vessel above and below the injury. If the vessel cannot be found let the main trunk be tied.

If bleeding from a large vessel has ceased, it is not necessary to search for the vessel and tie it unless it is in sight. This rule holds if the patient is to remain under surgical observation; but if the patient is to be transported, if the hemorrhage has stopped because of heart weakness, or if the patient may become delirious or unquiet, it is usually best to find the vessel and tie it. The emergency control of bleeding is best made by pressure locally or by a tourniquet above the wound. Shock should not be added to hemorrhage. After the patient has reacted and fluids have been absorbed, the wound may be examined, and the vessel ligated. Often it is found that profuse bleeding comes from a wound in a branch near the main trunk; in which event the branch and not the trunk should be tied.

In internal hemorrhage which is not accessible, stimulation and fluids to increase blood-pressure should be used only as a last resort to save life. A state of anemia, keeping the patient upon the border of syncope, will often save life when the pernicious activity of exciting reaction would cause death. A clot that holds for six hours will usually hold permanently.

ARTERIES

Traumatism.—Traumatism to an artery may cause a rupture of the inner coats and the formation of an occluding clot. In such an event the treatment becomes that of thrombus or embolus. If the injury sufficiently damages the walls of the vessel, blood may be forced between the coats and a traumatic aneurism found (see Aneurism). Or the walls may give way entirely and hemorrhage into the tissues occur. Such hemorrhage usually stops when a sufficient amount of clot, to counteract the blood-pressure, has developed. Elevation of the part is of value. If the hematoma is small it needs no treatment but rest. If it is large or painful, or presses upon important structures, or steadily continues to increase, or is producing symptoms of anemia, and can not be controlled by pressure and cold, the vessel should be compressed above the seat of injury and the rupture cut down upon and dealt with.

Wounds of Arteries.—Wounded arteries usually require the treatment laid down for the control of hemorrhage. In a healthy adult, any artery in the body, excepting the aorta, may be ligated, and the collateral circulation may be expected to take its place. In the diseased or infirm, gangrene of parts results from the occlusion of large arteries, and every effort to preserve the circulation must be made. Even in the young the nutrition of a part is best carried through the great vessels, and they should be preserved whenever possible. The ligation of smaller vessels is a matter of small moment; but aseptic surgery has made it possible to preserve larger arterial trunks by suturing and by anastomosis.

The surgeon will often be at a loss to decide which course to follow: ligation or suture of the artery and attempt to preserve its circulation. In arteries below the middle of the brachial and below the popliteal, suture is rarely called for. In healthy persons the same may be said of the larger vessels of the extremities. But when the vein is injured at the same time, a very different situation exists. In the case of the artery and veins above the forearm and the leg, gangrene is apt to follow if both are occluded. In the event of a wound of both the popliteal artery and vein, not only is gangrene quite sure to occur, but a fatal termination is very common in this accident. The course to follow is to apply the rubber bandage constriction, cut down upon the injured vessels, and repair them in such a way as to restore their circulation. This repair should be preceded by cleaning out all of the clot which it is possible to remove. This may often be facilitated by making an opening in the vessel lower in the limb and washing through with salt solution.

If the surgeon has not experience and skill in this work, and the vessels are lacerated with loss of substance, the clots should be cleaned out and the proximal and distal ends tied.

Suturing of arteries is a well-established and successful expedient. It is best done with a fine, round, straight needle and silk thread of the smallest size. Some surgeons prefer fine paraffin silk or celluloid suture. For the largest vessels fine chromicized catgut is used by other surgeons The finest silk or Alsace thread No. 500 is used for small vessels; for larger vessels

fine cambric needles, sizes 6 to 10, threaded with size 0 or 1 oculist's silk. The silk should be not oversterilized lest it loose its strength. It should be rubbed with vaselin to prevent blood adhering to it.

Human hair is very satisfactory for suture purposes. Light brown hair of medium fineness, 20 cm. (8 inches) long, is used in No. 12 to 16 cambric needles, after being sterilized in aqueous solution of formalin and preserved in liquid paraffin.

For *temporary arrest of circulation* in a vessel, *temporary compression* is made with a soft clamp (Fig. 222). Such a clamp should be adjustable in its pressure in order not to injure the artery. Its arms should be covered with rubber. A clamp of this sort may be applied to a vessel for temporary occlusion while operating. It is used in all situations where it is desired to stop the circulation through any given vessel. Its special use is in suturing of vessels, and in operations on the head which would be bloody unless the circulation in the external carotid is temporarily shut off.

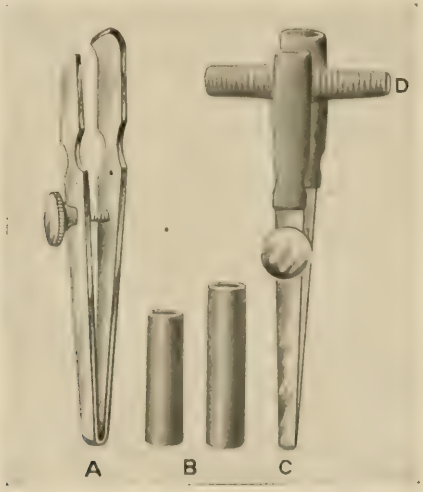


FIG. 222.—CLAMPS FOR TEMPORARY COMPRESSION OF BLOOD-VESSELS.
A, Spring clamp; *B*, rubber tubing for covering ends of clamp; *C*, clamp applied to artery *D*.

Experience has shown that serious coagulation need not necessarily be expected if the suture passes through the inner coat. Suture of arteries is not always absolutely successful; the artery is not always restored to its normal function in the circulation. Often a clot gradually develops at the site of operation, and eventually occludes the vessel, or its calibre is greatly narrowed. But even if these things do occur, the part supplied has been nourished and dilatation of the collateral circulation has been brought about gradually. In all work on blood-vessels if the intima is exposed, and it is important that coagulation should be prevented, the surface should be covered with liquid paraffin or vaselin, which seems to prevent the adhesion of clot. It prevents drying and thrombosis.

If the suture does not succeed in closing the wound, nothing worse than ligation of the artery is required to overcome the trouble. The operative area is rendered bloodless by the use of the soft clamps. If they are not to be had the blades of a straight clamp may be held gently upon the artery by means of an elastic band. The vessel should be clamped above and below

the wound. Care is necessary in order not to damage the intima. Or a temporary ligature may be lightly tied over a pad of gauze resting upon the artery. Tape is the best material for this purpose. The rubber bandage may be used instead of these methods.

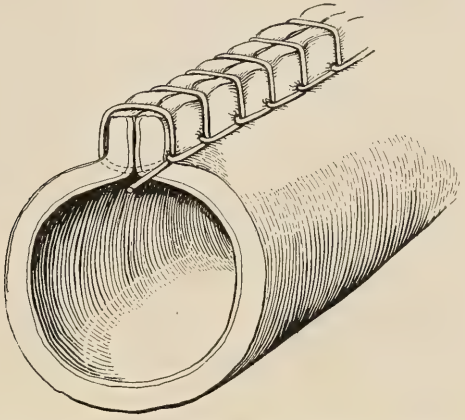


FIG. 223.—SUTURE OF LATERAL WOUND OF ARTERY.
Showing running chain stitch, opposing intima to intima.

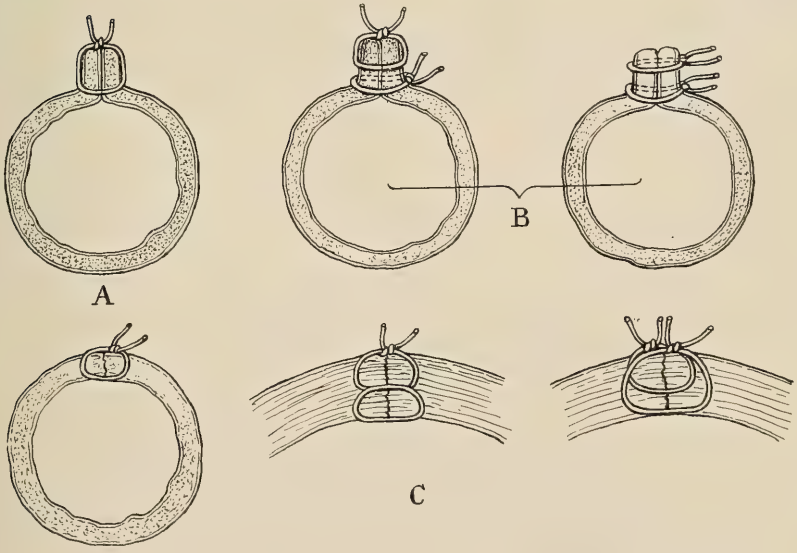


FIG. 224.—METHODS OF SUTURING LONGITUDINAL WOUNDS OF ARTERY.
A, Simple suture for smaller vessels; *B*, double suture for larger vessels; *C*, wound closure to preserve full lumen of vessel.

Lateral suture is applied for the closure of wounds not involving the whole circumference of the vessel. The suturing is done upon the same principles as are applied to intestinal suturing. A small wound is closed by a simple Lembert suture. The wound should be closely sewed, and the sutures tightly tied. The best results have been secured by everting the wound so that in applying the suture intima is opposed to intima (Fig. 223). This

method of suture was worked out by G. M. Dorrance (Annals of Surgery, 1906, vol. 44, p. 409).

If the wound is longitudinal a double layer of sutures may be applied, the outer layer being a reinforcing suture. The suture is best applied by first entering it about 3 mm. (⅛ inch) beyond the end of the wound. It penetrates only the outer and middle coats, and is tied. It is then con-

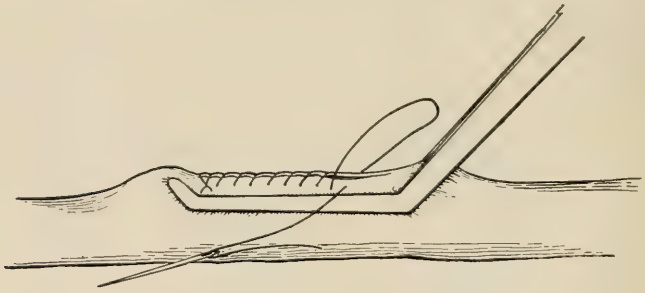


FIG. 225.—CLAMP OF JOANI WHICH PERMITS LATERAL SUTURE OF BLOOD-VESSEL WITHOUT INTERRUPTION OF THE BLOOD-CURRENT.

tinued, penetrating all of the coats and bringing intima to intima until the wound is closed. At every third stitch the suture is carried back the distance of a stitch to redouble upon itself for the sake of security. When the wound is closed the suture emerges, catches the two outer coats and is tied. This through-and-through mattress suture is reinforced by a second continuous suture taking up the edges between the loops of the first suture. If these sutures are nicely applied the thread is not exposed to the blood-current (Fig. 224).

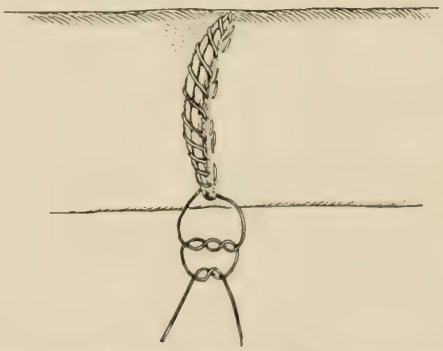


FIG. 226.—SUTURE OF TRANSVERSE WOUND OF ARTERY.

A most useful appliance for controlling bleeding while a longitudinal wound of an artery or vein is being sutured is the clamp of Joani (Fig. 225), which obviates the necessity for completely shutting off the blood-stream while the suture is being applied to a large vessel. Transverse wounds are closed by the same method (Fig. 226).

Large ragged wounds or large transverse wounds require complete division of the vessel and *end-to-end anastomosis*. This is best done by everting the ends and making an intima-to-intima suture all the way around the vessel

just as is described for the lateral suture (Fig. 227). This is best done with the aid of three or four guy sutures which are first placed at equal intervals

FIG. 227.—END-TO-END SUTURE OF ARTERY.

FIG. 228.—END-TO-END SUTURE OF ARTERY OR VEIN.
Method of applying stay sutures to facilitate the sewing.

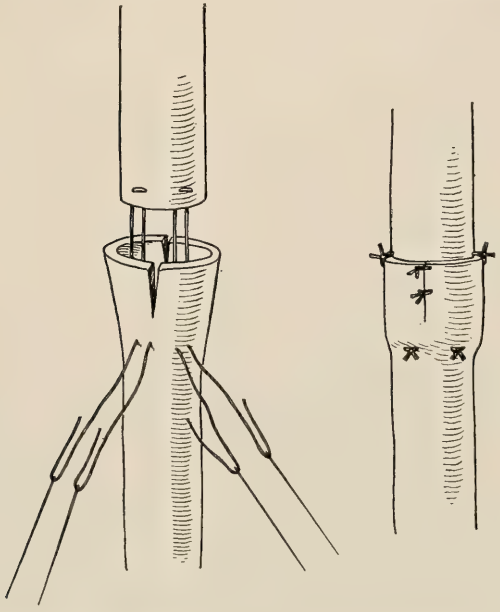


FIG. 229.—INVAGINATION METHOD OF END-TO-END SUTURE OF ARTERY.

about the vessel after the method of Carrel (Fig. 228). A second outer layer of sutures may be applied also, as in the lateral suturing.

Another method is by invaginating the proximal end into the distal end. In order to accomplish this the outer surface of the proximal end must be well cleaned of connective tissue. It is possible in large arteries to remove the outer coat and thus diminish the size of the vessel to be invaginated (Fig. 229). In some cases a longitudinal split must be made in the distal

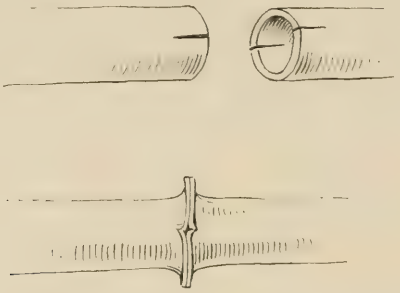


FIG. 230.—METHOD OF WIDENING MOUTH OF VESSEL TO FACILITATE END-TO-END SUTURE.

end, which is closed by longitudinal suture after the other fixation sutures have been applied. This method by invagination is quite apt to be followed by thrombosis.

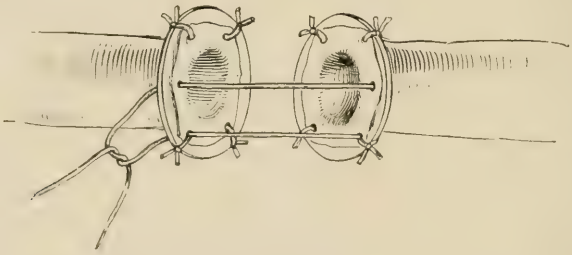


FIG. 231.—ABSORBABLE MAGNESIUM RINGS USED FOR ANASTOMOSIS.
Showing method of everting intima and uniting rings.

By squarely cutting the two ends to be united, and then making a longitudinal incision in each end on each side for about 6 mm. (¼ inch), two flaps are formed which facilitate end-to-end anastomosis (Fig. 230).

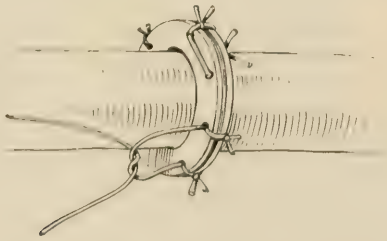


FIG. 232.—MAGNESIUM RINGS UNITED; TWO SUTURES TIED; THIRD SUTURE ABOUT TO BE TIED.

The use of *absorbable magnesium rings* is an aid in blood-vessel suturing. The metal magnesium is made into thin rings (Fig. 231). It is dissolved by fluids containing salt, and, therefore, should be sterilized in pure water. In the tissues the rings begin to melt away in about thirty days, and in from eighty to a hundred days the metal has disappeared. Rings of various sizes

are provided. The exact diameter of the distended vessel is taken with a millimeter measure, and the corresponding rings selected. The two occlusion clamps should be about 4 cm. (1½ inches) apart. If necessary they may be closer. Sheath and adventitia are cleared away. Lespinasse, Fischer, and Eisenstaedt (Jour. Am. Med. Assoc., Nov. 19, 1910) successfully used the rings in four different ways: (1) one ring and a lock-stitch; (2) one ring sewed to the end of each stump and the two united; (3) two rings and four ligatures; and (4) two rings, one of which is threaded. The second method is to be preferred (Fig. 232). These authors have also used *lateral plates* for suture of vessels.

End-to-end anastomosis is an operation which is being performed successfully in all active surgical clinics. In wounds and fractures with tearing across of large vessels, such as the brachial and femoral arteries, it is applied with a large measure of success. The lumen of the vessel and the circulation are restored. In a certain proportion of cases clot forms at the seat of opera-

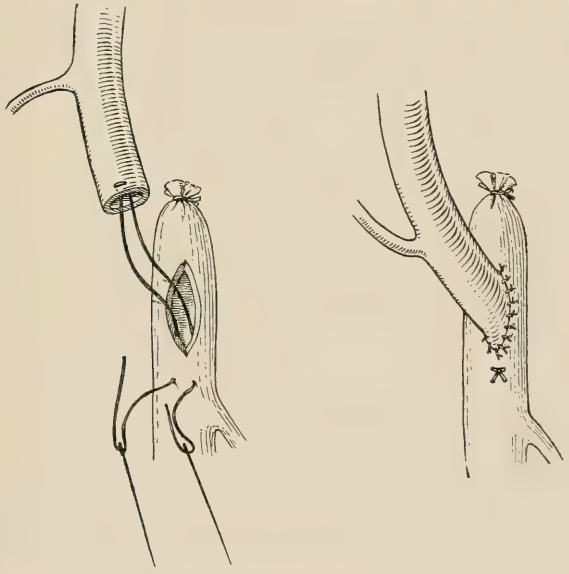


FIG. 233.—ARTERIOVENOUS ANASTOMOSIS BY LATERAL IMPLANTATION.

tion. This is best obviated by care in handling the vessel. The endothelial lining should be traumatized as little as possible. Before making the union clots should be removed and washed out with warm saline solution. If clot forms and the vessel becomes occluded after the anastomosis has been made, the vessel should be incised longitudinally near the anastomosis, the clot removed, and the wound sutured. After finishing a suture the distal clamp always should be removed first.

Arteriovenous anastomosis has been performed successfully for threatened gangrene, due to arterial occlusion, in both the femoral and brachial arteries. It is especially useful in endarteritis. J. Wieting did it by lateral implantation (Fig. 233). The operation may be done by end-to-end anastomosis, the artery and vein being cut squarely across, or by lateral anastomosis. Lateral anastomosis between artery and vein (Fig. 234) is easily done and proves quite as successful as the other operations. The vein should be tied above the anastomosis, otherwise the blood from the artery will return di-

rectly to the heart. There are some successes with this operation in impending gangrene, but usually it fails to give relief.

This operation has in many cases been successful in restoring the life of the extremity. A sense of fulness is felt in the vein into which the arterial blood pours. Pain often results from the pressure. Where clot forms, it is always worth while incising the vein just beyond the anastomosis and remov-

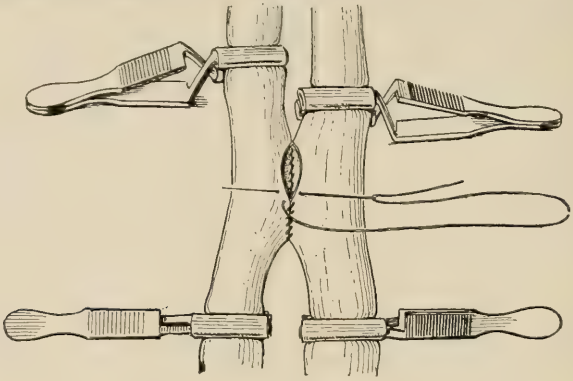


FIG. 234.—LATERAL ANASTOMOSIS OF BLOOD-VESSELS.
The posterior row of sutures has been inserted; the anterior row is being placed.

ing the clot. After arteriovenous anastomosis has been done the distal part of the artery should be cleaned out by catheterization and irrigation. If it can be made to bleed, a second anastomosis should be made between the distal limb of the artery and the proximal limb of the vein, if end-to-end operation has been done. If it does not bleed the distal stump of the artery and the proximal stump of the vein may be tied (Fig. 235).

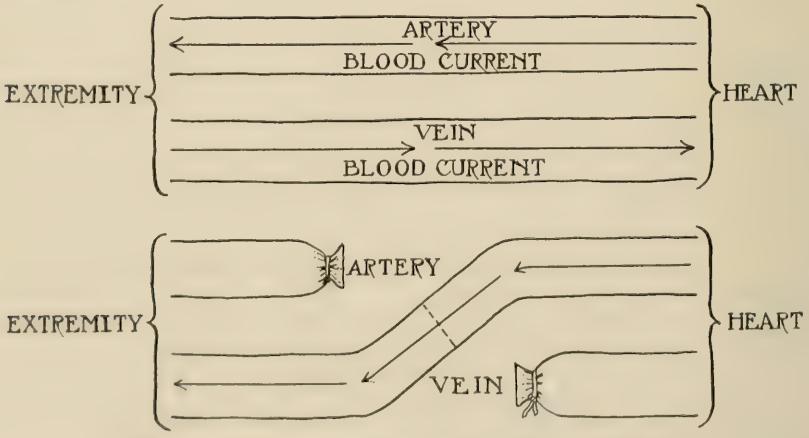


FIG. 235.—DIAGRAM OF ARTERIOVENOUS ANASTOMOSIS.

Payr advised using the deep femoral artery for this operation. It is nearly as large as the femoral, and, if thrombosis occurs, the main artery is still intact.

A very useful clamp has been devised by J. S. Horsley (Annals of Surg., May, 1915) for lateral anastomosis. It consists of a simple curved forceps with very light blades which may be covered with rubber tubing (Fig. 236). These clamps may be used also for operating on arteriovenous aneurism.

In the anastomosis of blood-vessels it is essential that all connective tissue be removed from the vessel. The adventitia should be removed carefully from the areas of apposition. The exposed vessels should be kept covered

FIG. 236.—LATERAL UNION OF ARTERIES OR VEINS WITH AID OF ANASTOMOSIS FORCEPS. The posterior row of sutures is being placed.

with vaselin, liquid petrolatum or paraffin to prevent drying. If this is not done, thrombosis is apt to occur. The fine silk suture sinks into the intima and disappears and the intima becomes smooth.

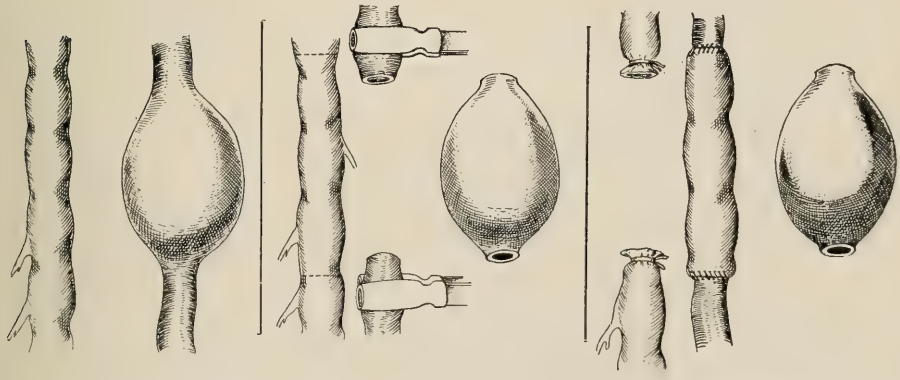


FIG. 237.—SEGMENT OF VEIN USED TO UNITE ARTERY IN WHICH A GAP HAS BEEN CAUSED BY LOSS OF CONTINUITY DUE TO REMOVAL OF ANEURISM.

In this operation there is danger of the formation of an occluding thrombus. A better result is secured by end-to-end anastomosis in which no raw surface is exposed to the blood current. (*After Keen.*)

In case of *loss of substance* in an artery, leaving a space through which the ends can not be approximated, a segment of the accompanying vein may be used to fill the gap. In performing this operation the vein should not be lifted out of its bed and severed from its connective-tissue connections any

more than is absolutely necessary, for fear of disturbing its nutrition. All sutures should be in readiness and such as can be applied to the artery should be applied before cutting the vein. An adequate amount of vein should then be cut above and below, after ligating in two places. The artery should be allowed to bleed slightly to wash out any clot that has formed, and then the anastomosis proceeded with by the same method as is described for arterial anastomosis (Fig. 237). This operation has been done successfully in the femoral artery by several different surgeons.

After completing the suture of an artery the distal clamp should be removed. The proximal clamp should then be slowly relaxed gradually allowing more and more blood to flow through the sutured segment. If there is leakage the clamp should be reapplied and a suture added where needed. In closing the overlying wound the best support possible should be given the vessel by suturing fascia and muscle firmly in place. The part should be kept at rest by a firm dressing, held with adhesive strips and a splint to immobilize the joints. Not a large dressing should be used, as it is desirable that the first signs of bleeding shall be revealed.

The catheterization of arteries is of value in cases in which amputation has been done for gangrene, due to embolism, and the artery is found occluded by a clot at the place of amputation. The danger of gangrene of the stump and the necessity for higher amputation may be obviated by passing a lubricated catheter or sound into the artery to dislodge the clot. By this method the patency of the artery and the nourishment of the soft parts may be restored.

Arteritis.—In the treatment of all forms of arteritis measures to reduce arterial tension should be applied, if it is high.

Traumatic arteritis requires rest in bed with the affected limb quiet, relaxed and slightly elevated. *Infective arteritis* requires the same treatment with the addition of measures to combat the infection. It is customary to apply such local antiseptics as oil of wintergreen or ichthyol, although their efficacy is doubtful. The disease either subsides, results in a local abscess, or the infection is swept to other parts. Usually a thrombosis occludes the vessel, and the treatment of gangrene may be required. When the arteritis is due to syphilis, antisyphilitic treatment should be pushed. *Chronic arteritis* is usually a sequel of chronic constitutional disease. Syphilis, alcoholism, chronic autotoxemia are the conditions usually requiring attention. The improvement of the general hygiene is of the utmost importance. These patients are candidates for apoplexy, aneurism and gangrene of the extremities. They should guard against physical exertion. Wounds or the smallest infected scratches of the digits are dangerous.

Aneurism

The treatment of aneurism must depend upon the nature of the lesion. In **traumatic aneurism,** in which a vessel has been ruptured, the treatment is the same as that for wounds of arteries (page 334). If the aneurism is of slow formation, and there is no urgency on account of anemia or pressure, operation should be delayed while a sac forms with a lining of endothelium and the collateral circulation has developed. This rule applies also to the other forms of aneurism which are discovered in this early stage. From four to six weeks is the minimum of time required for the maturing of an aneurism. **Dissecting aneurism,** due to hemorrhage into the layers of the middle coat, through an ulcer or break of the intima, occurs in the aorta, and must be treated as chronic aneurism. The common aneurism is that

which develops in diseased arteries and is called *chronic aneurism*. Its treatment should first be constitutional and aimed to correct the causative factors.

Hygienic treatment should correct all errors of living, diet and habits. Syphilis should be treated, if present. Alcohol, tobacco, coffee and other poisons should be stopped. If the blood-pressure is high, measures for its reduction should be applied. Whether or no syphilis is present, iodide of potash in doses of 1.2 Gm. (20 grains) thrice daily, is of service in lowering blood-pressure and relieving pain. Active exercise or muscular straining are dangerous. In inoperable aneurism, much toward checking the progress of the enlargement by these measures may be accomplished, and it may be hoped that coagulation within the sac may obliterate it. To favor coagulation in sacculated aneurism, rest in bed and the reduction of the diet nearly to starvation to diminish the total amount of blood are essential. Tuffnell restricted fluids, kept the patient thirsty, and gave the patient in twenty-four hours 120 Gm. (4 ounces) of bread, a little butter, 240 c.c. (8 ounces) of milk and 90 Gm. (3 ounces) of meat or egg. A little fruit juice should be added. This restricted diet and quiet are persisted in for several weeks at a time.

Medical treatment has been of doubtful service. The value of iodide of potash is questionable. Lactate or hydrated chloride of *calcium* is said to increase coagulability of the blood. *Gelatin* has been used for the same purpose. It is injected into the subcutaneous tissues with aseptic care. Every five or ten days, 50 to 100 c.c. of a 1 to 5 per cent. solution in normal salt solution are injected. Ten, twenty, or forty injections may be used. The 1 per cent. gelatin solution is made by dissolving 5 Gm. of gelatin in ½ liter of warm normal salt solution in a flask. The fluid is then cooled to 40°C., the white of an egg stirred in, the flask put in a water bath, and boiled. The egg coagulates and clears the solution, which should then be filtered, first through gauze and then through filter paper. The fluid is then put in sterilized test-tubes, plugged with cotton, and the tubes sterilized in a steam sterilizer for fifteen minutes for three successive days. The cotton should then be covered with rubber caps or hot paraffin to prevent evaporation of the water. Too much heat impairs the coagulability of the gelatin; too little heat fails to render it safe for injection. Tetanus has resulted from failure to sterilize. Death has been caused by making the injection too rapidly into a vein. Gelatin may be given by mouth, but with less efficacy. If there is any value in the gelatin treatment, it would be better secured by direct infusion of gelatin solution into the blood-stream (see Gelatin in Shock, page 347).

Electricity is used with good effect in aneurism of the aorta. The method makes use of the properties of the anode, which is placed over the tumor to cause coagulation upon the walls of the sac, stimulate the sac to contraction, improve the nourishment of the part, and cause an irritative reaction which causes a continuation of coagulation. A current of relatively large quantity is used under medium or feeble tension. A positive constant current of 50 or 60 milliamperes is applied to the external surface of the tumor and the negative pole to the near vicinity. This is done daily for fifteen minutes. The total results are poor.

Compression of the artery above or below the aneurism was useful before aseptic surgery made ligation free from danger. Digital and instrumental compression of the vessel are now used only in the absence of surgical help. Such compression is applied directly to the vessel for half an hour or longer. An anesthetic is given in some cases and the occlusion of the vessel kept up for an hour. The object is to produce stasis and coagulation in the sac. In-

cidentally, the greatest advantage is development of the collateral circulation. Cures are accomplished by this treatment.

Wire has been introduced into the sac to provoke coagulation. This treatment is best applied by exposing the aneurismal sac and passing through its wall through a canula fine wire which has been smoothly rolled and sterilized, and which will curl up as it enters the sac. Steel, gold, silver and bronze wire have been used. Several feet or yards of this wire may be pushed in, care being taken that it shall curl up in the sac and not in the vessel. Silver wire has also been used. The wire is left in an hour or more till a good clot has formed.

Wiring and **electrolysis** are successfully combined. A hollow insulated needle is passed into the sac of, say an aneurism of the aorta, and 10 to 40 feet of gold wire passed into the sac through the needle. A galvanic current is then passed through the wire. Beginning with 5 milliamperes, the current is increased by 5 additional milliamperes every five minutes until 50 milliamperes are reached, and then the current is gradually shut off. The positive pole should be connected with the wire. The negative pole should be applied to a flat surface in the vicinity of the aneurism. The best wire for the purpose is yellow gold. Silver does not curl sufficiently. The best results were reported by H. A. Hare (Jour. Am. Med. Assoc., Apr. 18, 1914) who in twenty-five cases of aneurism of the aorta secure benefit to the patient in all and had no accident in any. The diagnosis of sacculated aneurism should be made by the *x*-ray, as the treatment cannot be used in fusiform aneurism.

Irritation of the sac to provoke coagulation has also been produced by scratching the inside with needles (Macewen). This method is now abandoned. Catgut has been introduced to form a nucleus for coagulation similar to wire.

All of these treatments, aimed to secure coagulation in the sac, are of use only in aneurism that is distinctly sacculated. In fusiform aneurism they cannot be employed. These measures are chiefly applicable to the disease in the thoracic aorta and its thoracic branches. Aneurism that is operable, that is aneurism outside of the thorax, is best treated by operation.

Aneurismal sacs outside of the thorax have been treated by digital **compression** of the artery in order to secure stasis of blood and coagulation. The compression is best applied on the cardiac side. Digital compression is preferable to instrumental compression because it is less painful and does less damage to the artery. It is extremely difficult because relays of assistants must be employed. The pressure must be sufficient to completely occlude the vessels, and must not be interrupted for a moment. It should be continued for twenty-four or forty-eight hours. Many surgeons have applied mechanical devices to the same end. Exposure of the vessel and the use of relays of temporary arterial occlusive clamps are feasible. This treatment by pressure is now but little used.

Ligation of the artery (Fig. 238) and occluding bands are of great service in this disease. The ligation may be done either above or below the aneurism, or both. Prior to the second century, so far as we know, aneurism was not operated upon, and was regarded as a fatal disease over which art had no control. In the second and third centuries Antyllus described an operation which he had performed. He ligated the artery immediately above and below the aneurism, incised the tumor and emptied out its contents. This was probably because at that time it was believed that the sac contained noxious materials which were responsible for the disease. The circulation of the blood was not then known. During the intellectual darkness of the middle

ages not only no advances were made in the treatment but even the excellent operation of Antyllus fell into disuse. In the sixteenth century the operation was revived. In 1710 Anel ligated only above the sac, doing nothing more, and secured a cure. Ligation of the artery on the proximal side some distance above the sac was first done by Desault in June, 1785. Six months later the operation was done by John Hunter, following his experiments in ligating vessels in dogs. This high operation possesses the advantages that

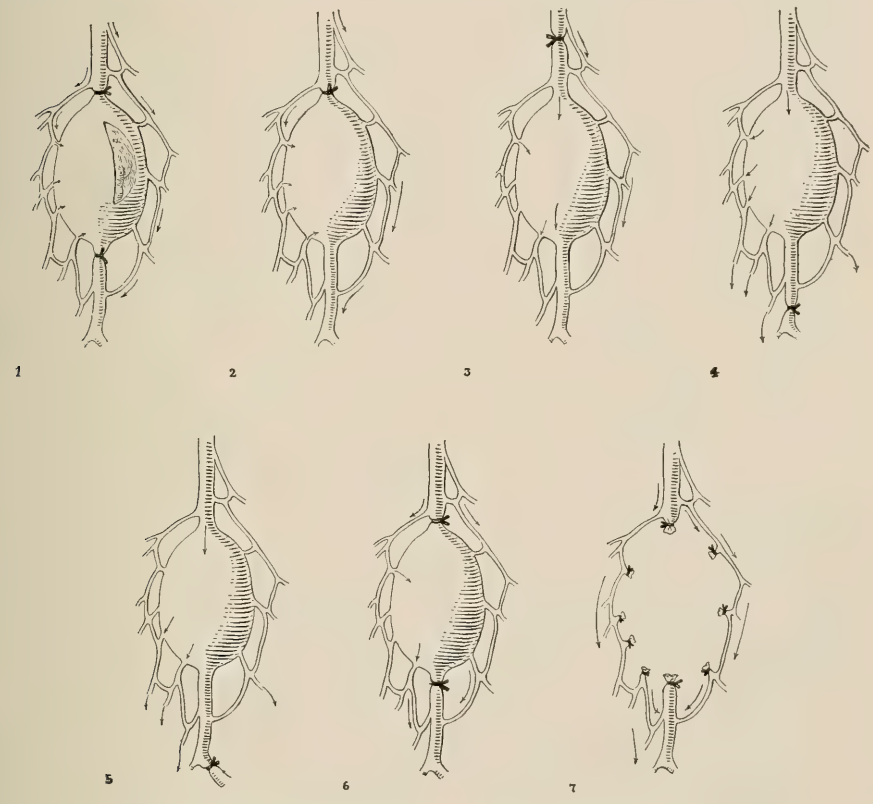


FIG. 238.—VARIOUS METHODS OF LIGATION FOR ANEURISM.

1, Antyllus; 2, Anel; 3, Desault-Hunter; 4, Brasdor-Deschamps; 5, Wardrop; 6, Pasquin; 7, Philagrius-Purmann. In (1) with incision of the sac and packing hemorrhage may take place through the collateral supply. In (2) and (3) the blood enters the sac again through the collateral branches. In (4) and (5) the blood passes through the sac and thence around the ligated trunk and enters it below. In (6) the collateral circulation may permit the entrance of blood into the sac and around the ligated trunks. In (7) the sac is removed without interference with the circulation. (*After Keen.*)

the ligation is done in a healthier part of the artery, and the danger of the aneurism being fed by a collateral branch is not so great. It often happens that proximal ligation can not be practised because of inaccessibility or nearness to the thoracic aorta, as in aneurism of the lower part of the common carotid. Here ligation on the distal side shuts off the blood-current, passing through the disease, and permits coagulation in the aneurism. This is the operation advised by Brasdor. Distal ligation alone of a thin-walled aneurism is dangerous. Wardrop ligated distal to the first large branch beyond the aneurism (Fig. 238).

Gradual obliteration of arteries was most effectively worked out by W. S. Halsted (Jour. Exper. Med., xi, 1909) who used aluminum bands with smoothed edges. They are placed around the artery and tightened by pressure with the fingers. They should be about as wide as the diameter of the vessel, sheet metal gauge No. 23. This is 0.6 mm. in thickness. The widths used are 8 mm. (5/16 inch), 6 mm. (1/4 inch) and 4.5 mm. (3/16 inch). Matas had the bands cut and bent in the form of an aneurism needle. This is hooked about the vessel, compressed by the fingers of the operator until the pulses are obliterated, and then the excess of the band cut off with strong scissors. Or the end may be bent up to form a catch (Fig. 239).

These bands have been used on the common carotid, subclavian, and other large arteries. The advantage of this method is that a gradual occlusion or narrowing of the vessel allows time for the dilatation of the collateral vessels and establishment of a collateral circulation, which often fails to occur when a vessel is suddenly ligated. Gangrene and other disturbances incident to instantaneous shutting off of a large vessel are prevented. A vessel may be narrowed by this method to the point of shutting off pulsation while circulation is still adequate to nourish the part. Obliterating endarteritis closes the vessel in three or four days. The band can be released at any time upon the appearance of signs of ischemic paralysis. No gross changes are observed in the vessel during the first three days. The band becomes permanently encapsulated and does no harm. Up to seventy-two hours the band may be removed, if desired, and the circulation restored.

FIG. 239.—ALUMINUM METAL BAND COMPRESSING ARTERY.

Note that the band is bent to form a catch like a safety pin.

J. M. Neff (Jour. Am. Med. Assoc., Aug. 26, 1911) devised a clamp which is drawn together by elastic bands. Between the blades of the clamp are wound several layers of catgut, to hold the blades apart so that they make pressure on the artery but not enough to stop the pulses. Rubber bands cause the compression. The catgut is gradually softened and absorbed in from three to four weeks. During this time the pressure is being increased by the rubber bands, which ultimately cut the vessel in two.

Surgery is not necessarily committed to the use of metallic appliances for this purpose of occlusion. Ligatures of chromicized catgut, kangaroo tendon, silk or linen may be used. Decalcified bone, magnesium, or other slowly absorbable hard substance may be employed. Latterly the use of strips of fascia taken from the patient have been used most effectively. The important thing is the principle of a partial or gradual occlusion, applied in such a way that the intima of the vessel is not at once injured, and which may be removed or loosened at will. It is the idea of giving consideration to the development of the collateral circulation that gives this method its value.

The **plication of arteries** to reduce their caliber may be applied to the large vessels. With a fine milliner's needle and fine silk, interrupted mattress sutures are introduced around the artery through all the coats external to the intima, and the size of the vessel reduced by longitudinal infolding.

Aneurismorrhaphy, or the closure of aneurism by suture, is the modern operation, which may be employed in sacculated aneurisms, in arteries in which it is feasible to shut off the blood-current temporarily during the operation. This operation was perfected by R. Matas of New Orleans.

It aims at the local treatment of the aneurism and cures (1) by closure of

the opening from the vessel into the sac, (2) by the reconstruction of a vessel lumen, or (3) by the obliteration of the sac by suture. The choice of operation must depend upon the conditions found. These operations are not indicated in aneurisms in vessels so small that their ligation would not materially interfere with the vitality of the parts supplied. In such cases it is preferable to ligate above and below and excise the sac. It is in the larger arteries, at the elbow and knee and upward that the operation of aneurismorrhaphy is applicable. If the opening into the sac is large and the wall of the artery has become a part of the wall of the aneurism, or if the disease is a fusiform aneurism, there is little possibility of doing a restorative operation. In such a case the reconstructive or the obliterative operation is indicated. But if the opening into the sac is not large, and the artery is really external to the aneurism, a restorative operation, to close the opening into the sac, to preserve the lumen of the vessel, and to obliterate or remove the sac is indicated. In the larger vessels a restorative operation is most important; and it is probable that future experience will give the restorative operation a wider and wider field of application.

The **operation of endo-aneurismorrhaphy** is carried out in vessels of the extremities by first rendering the limb ischemic by the rubberbandage method. This is advisable in all cases excepting those in which there is defective circulation in the extremities; and here it is better to shut off the circulation only in the vessel to be operated upon. This can be done best with the temporary compression clamps (Fig. 101). Or temporary ligation may be practised, the ligature being a large, soft, silk or linen tape, tied lightly down upon a gauze pad overlying the artery. Digital compression is preferable in the aorta and iliacs. The surgeon should always have in mind the branches of the artery coming off at the aneurism. It is the control of these that gives this method its value. But where the ischemic bandage cannot be used, the surgeon must bring to bear his anatomic knowledge in determining where to apply the pressure. Below, the pressure should be applied as near the aneurism as possible; above, it should be applied high enough to cut off the supply to branches which anastomose with branches coming off at the aneurism. Sometimes this is impossible. Then, when the best hemostasis attainable has been secured, the surgeon may ligate the branches coming off at the aneurism, or close their mouths after opening the sac. In aneurism of the axilla, the elastic bandage may be applied as near to the aneurism as possible, and then the vessel controlled from above by compression of the subclavian.

The aneurism should be exposed by a free incision in the direction of the long axis of the vessel. The sac should not be dissected away from its surrounding tissues, but it should immediately be opened and emptied of clots. The sac should then be retracted widely; and the surgeon notes the number of arterial openings. In sacculated aneurism but one opening into the main artery is seen. In fusiform aneurism two openings, usually connected by a groove, representing the remains of the vessel lumen, are observed. In all of these operations, clots should be removed from the main vessel and its branches as far as possible.

The **obliterative operation** is found most commonly applicable. It should have been preceded by measures to create an efficient collateral circulation. The sac is freed of clot. Fibrin near the orifices is wiped away. The orifices of the artery are then sutured from the inside of the sac, being closed with chromic catgut sutures, inserted with a small round needle. The suture may be continuous or interrupted, depending upon the length of closure required (Fig. 240). The walls of the aneurism are usually tough and a strong suture is necessary. The stitches should be 2 or 3 mm. (⅛ inch)

apart, and should include a good bit of tissue. The suture should be inserted about 4 to 6 mm. ($\frac{1}{6}$ to $\frac{1}{4}$ inch) from the opening, pass to the floor of the inside of the artery, enter the opposite side of the wall of the artery

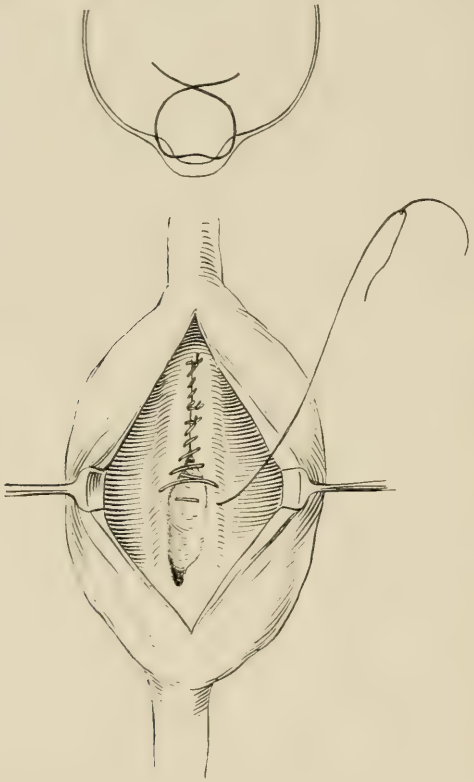


FIG. 240.—OBLITERATIVE ENDO-ANEURISMORRHAPHY.
Operation of Matas. The suture closes the vessel and all arterial openings

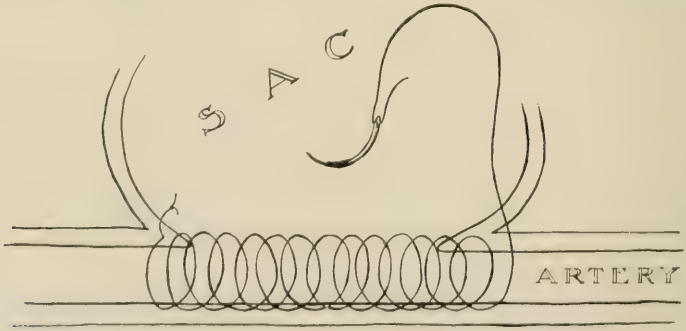


FIG. 241.—DIAGRAM SHOWING RELATIONS OF SUTURE IN OBLITERATIVE ENDO-ANEURISMORRHAPHY.

again, and emerge inside of the aneurism at a point opposite to its entrance (Fig. 241). This suture may be applied separately to each orifice; or it may close one, then close the groove connecting the two, and then close the other.

Openings of branch arteries are closed separately. It is important that these should not be overlooked. A second layer of sutures may be introduced, folding another layer of aneurism wall over the first line of sutures. After

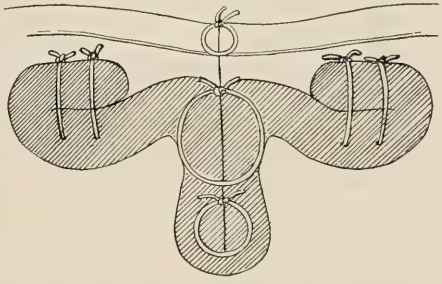


FIG. 242.—OBLITERATION OF SAC AFTER INTERNAL SUTURES HAVE BEEN APPLIED, AND THE CLOSURE OF THE VESSEL HAS BEEN PROVED.

This diagram shows a cross-section of the result, after all sutures, closing aneurism and skin have been inserted.

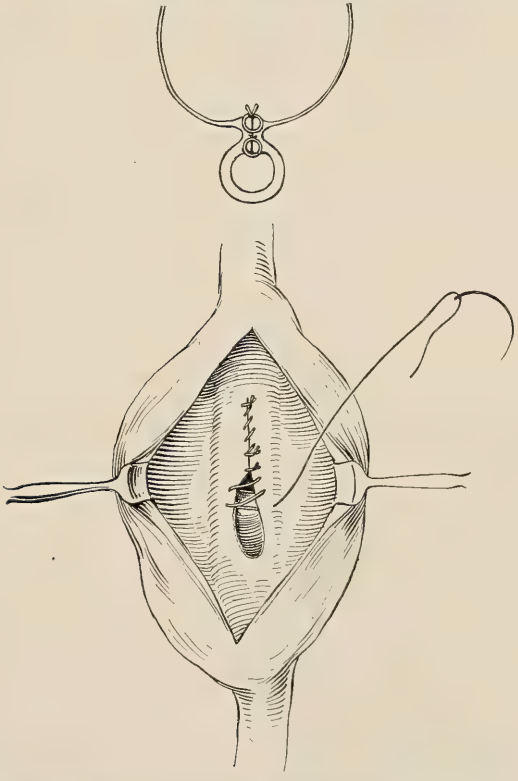


FIG. 243.—RESTORATIVE ENDO-ANEURISMORRHAPHY.

The suture avoids the lumen of the artery but closes the opening between the artery and the sac. Operation of Matas.

these sutures have been applied the pressure to stop the circulation should be relaxed in order to observe if the arterial closure is blood-tight. If a leak shows itself the pressure should be reapplied and additional sutures inserted.

The *obliteration of the sac* is the next step. This is accomplished by folding the sac wall upon itself, thus leaving no cavity requiring drainage.

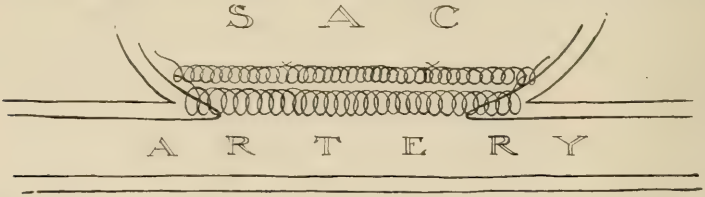


FIG. 244.—DIAGRAM SHOWING TWO ROWS OF SUTURES CLOSING OPENING BETWEEN SAC AND ARTERY BUT NOT ENCROACHING ON LUMEN OF THE VESSEL.

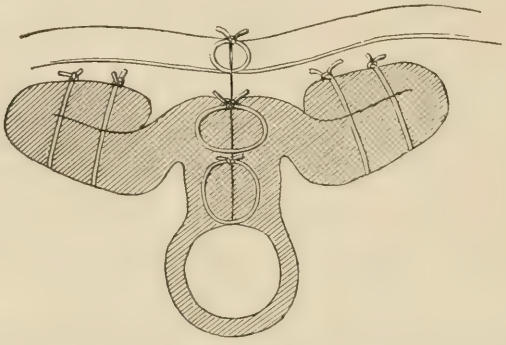


FIG. 245.—DIAGRAM SHOWING SUTURES IN RESTORATIVE ENDO-ANEURISMORRHAPHY AND OBLITERATION OF SAC.

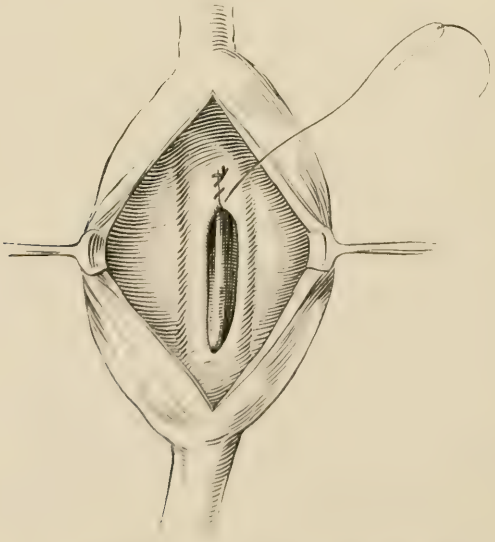


FIG. 246.—RECONSTRUCTIVE ENDO-ANEURISMORRHAPHY.
Mastas operation. A rubber tube has been placed on the floor of the sac in a line representing the continuity of the artery.

Any redundant portion of the sac that can easily be cut away is removed. Sutures of strong material catch the deep part of the sac, then pass through the more superficial part and the skin, thus compressing the walls of the sac.

These sutures should not be passed completely through the deep part of the sac lest they engage nerve or vein (Fig. 242).

The **restorative operation** is applied to aneurisms in which the artery has not become spread out to form a part of the sac. A single opening exists from the vessel into the sac. This may be closed by a continuous suture. The suture should catch up the inside of the sac and emerge close to the arterial lumen but not encroach upon it (Fig. 243). The suture is in contact with the blood-stream. The more tightly it is applied the less thread is exposed

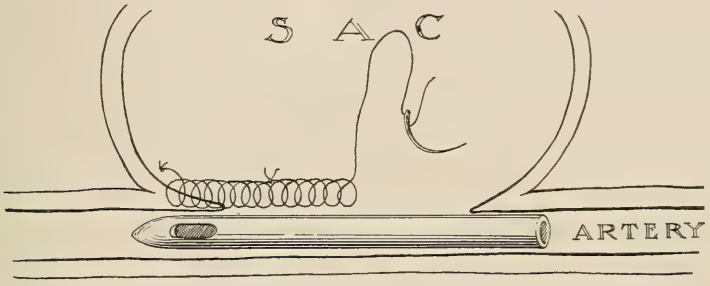


FIG. 247.—DIAGRAM SHOWING METHOD OF RECONSTRUCTIVE ENDO-ANEURISMORRHAPHY
A piece of soft rubber catheter is placed in the vessel as a guide for reconstruction.

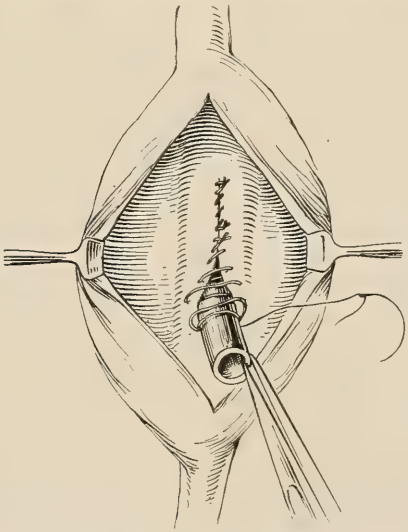


FIG. 248.—RECONSTRUCTIVE ENDO-ANEURISMORRHAPHY.
Rubber tube being removed before completing closure of opening.

to cause coagulation. A second row of sutures, reinforcing the first and covering it with a layer of sac-wall, may be inserted (Fig. 244). The sac-wall is then obliterated as described above. The skin may be sewed separately, the obliterating sutures involving only the sac (Fig. 245).

The **reconstructive operation** is aimed to restore a lumen for the artery in cases in which it has become spread out into the aneurism. Matas suggested the application of this method to fusiform aneurisms of large vessels. A piece of rubber catheter of the size of the lumen of the vessel should be laid down upon the floor of the sac connecting the two openings.

This serves as a mold, over which the wall of the sac is sewed with continuous or interrupted sutures of chromic catgut (Fig. 246). Before the last sutures are tied the tubing is removed (Figs. 247 and 248). A second layer covering the first should be added, and the sac infolded to produce obliteration of its cavity.

These operations require much more time than simple ligation. So far as the nourishment of the extremity is concerned, it amounts to the same, whether a vessel is occluded by clot, sutures or ligature. Gangrene will follow one as quickly as the other. The great advantage of endo-aneurismorrhaphy is that it gives the surgeon the opportunity to inspect the sac, close collateral branches communicating with it, and effecting its obliteration. It is more sure to cure than ligation above and below, combined with obliteration of the sac, because a communicating vessel might emerge between the ligature and the sac. The reconstructive and restorative operations may be expected to be followed by thrombosis; but it may be hoped that the clot formation will be gradual, and that the other vessels to the part will become sufficiently dilated to supply an adequate circulation before complete occlusion occurs. The reconstructive operation is apt to be followed by recurrence of the aneurism because of the fact that it deals with diseased arterial wall. These operations aim toward an ideal in surgery; greater perfection may be attained, whereas, ligation for aneurism can not advance much farther than it has.

Tests of the efficiency of collateral circulation are important as a preliminary to the occlusion of large arteries. R. Matas (Jour. Am. Med. Assoc., Oct. 24, 1914) discussed this subject fully. When the pulse of a large artery has become obliterated beyond the point of disease and the nourishment of the extremity remains good, Delbet has shown that this signifies that collateral circulation is adequate and the main artery may be tied. If blood flows from the distal opening in an incised aneurism sac after a clamp is placed on the main artery above the sac, it may be assumed that the collateral circulation is established, although it will often be found that the circulation does not extend far enough beyond the aneurism to prevent gangrene of the extremity. Von Frisch showed that if the proximal side of an injured artery is compressed, the integrity of the collateral circulation is shown by the "living color" of the peripheral skin beyond, by the bleeding from the peripheral side of the wound in the vessel, and by the venous stasis which appears below the main vein when it is compressed. The test of Tuffier and Hallion consists in placing an elastic band about the part, say, above the ankle if the foot is to be studied, just tight enough to compress the superficial veins. If blood is flowing into the part venous turgescence will be observed. If the main artery is closed by digital pressure, and the band applied, the appearance of venous turgescence means that the collateral circulation is adequate, and the artery may be closed if necessary. If edema and venous obstruction already exist in the extremity this method can not be applied. Stuart has worked out a calorimetric test whereby the heat carried to a part by the blood-current may be estimated; and Korotkow and Pachon have devised delicate manometric tests for determining the blood-pressure in the part.

Matas, recognizing the usefulness and the deficiencies of these tests, directed attention to the tests which he devised in 1907 and which have proved to be the simplest and most reliable. The first depends upon the blush of living color suggested by Moskowicz. This test is used in the extremities wherever it is possible to compress the main artery of the limb. Ischemia of the limb is first secured by an elastic bandage applied from the

tips of the digits to the level of the disease. Then the main trunk is compressed by an accurately applied mechanical compressor which may act only on the vessel and not interfere with the collateral circulation. The compression should be applied close to the lesion (wound, aneurism, tumor) with sufficient force to arrest pulsation beyond if no ischemia were present. The elastic bandage is removed from the young in ten minutes and from the aged in five minutes. The main artery now being occluded, and as the bandage is removed, a hyperemic blush rapidly passes down the limb to a variable extent. Matas says:

> More often, the hyperemic wave stops, even in healthy adults, at a distance of 13 or 15 cm. (5 or 6 inches) from the compressor, or about one-fourth the distance down the limb from the level of the compressor. It then continues, in a subdued color and with irregular distribution, to travel toward the periphery; but the extreme end of the limb, foot or hand, and especially the digits, retain a cadaveric, waxy, lifeless pallor for several seconds, which may be prolonged to ten or forty minutes or even longer, according to the development of the collaterals. Then the waxy, bloodless color changes in patches to pale, but living color, which appears in various preferred areas, and gradually spreads uniformly and more or less intensely over the limb. In cases in which the collateral circulation is unusually developed, the hyperemic wave spreads in a few seconds throughout the whole limb as if the main artery had never been compressed. If the compression is kept up long enough there may be a temporary congestion, mottling and marbling of the skin, which is due to the simultaneous compression of the main vein. This is an additional sign that an efficient collateral circulation exists, as the veins could not become turgid without blood supplied by the collaterals.

In connection with such tests, it may seem best to defer operation while daily compression of the main artery is applied, along with massage of the limb, hot-air treatment, and measures to increase the blood-pressure, in order to develop the collateral circulation. By such treatment the collateral circulation may become so sufficient that any obliterating operation may be done with safety upon the main artery.

The second test upon which Matas relied is based on the use of the aluminium bands (see page 384). This method is applicable to arteries of the neck and trunk in which the test above described can not be used. He advised the application of these bands in all cases of aneurism or tumors involving the innominate, subclavian, carotid and iliac arteries. The band is applied, and, as a result of the arteritis set up by it, the vessel becomes occluded in the course of a few days. After this, if the peripheral circulation remains good nothing further is done. Often the aneurism is cured by this simple operation. If the circulation becomes defective after application of the band, it should be relaxed if the defect is noticed in the first two days.

The test, perfected by Moszkowicz, proceeds as follows: The blood is emptied from the limbs by elevating them and by elastic compression. Elastic bands are then applied at the roots of both limbs for at least five minutes, and then simultaneously removed. The redness which passes downward on each limb is noted. The test in the legs is more effective if the patient can be placed in the vertical position immediately upon removal of the constriction. A good light must be had. The arms are best tested with the patient in the horizontal position.

Aneurismectomy, removal of the aneurism, requires circular constriction at the root of the limb or compression of the feeding artery or arteries. In order not to destroy the main vein in a limb, a circular constriction should be applied to the limb below the aneurism. The rubber ischemic bandage is then applied from this level up to a place above the aneurism, at which permanent constriction is to be made. Upon removal of this rubber bandage, the aneurism lies in an anemic section, below which

there is a reserve of blood confined. When it is desired to identify the vein in the course of the operation the lower constriction may be loosened and the vein fills with blood.

The tumor is exposed by free incision. The vein should not be dissected free from the sac but that part of the sac to which it is adherent should be left attached to the vein. The patency of the vein is very important for the prevention of gangrene. This rule should be followed in the case of any important structure. As the sac is dissected out, the main artery, above and below, and all tributary vessels should be tied. Complete hemostasis should be secured by ligation. The remaining wound can not be packed with tampons lest the pressure cause gangrene. Asepsis is essential for success. The wound should be closed throughout with the exception of a small drain if indicated. The after-treatment should be the same as that for gangrene and its prevention.

This operation will be much more satisfactory if preceded by gradual obliteration of the artery, until the establishment of the collateral circulation is assured.

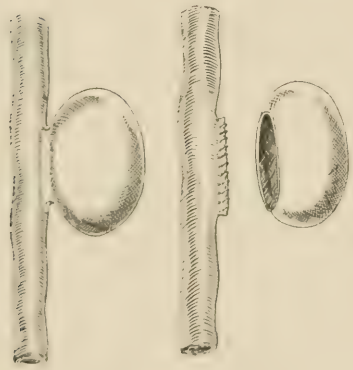


FIG. 249.—ANEURISMECTOMY WITH LATERAL ARTERIORRHAPHY. (*After Keen.*)

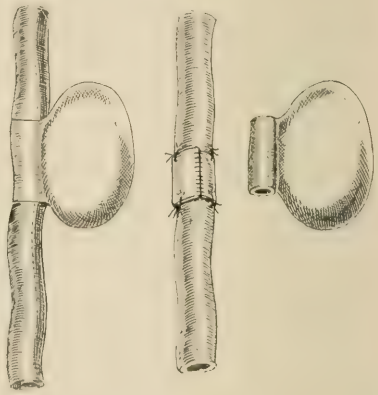


FIG. 250.—ANEURISMECTOMY WITH RESECTION OF ARTERY AND END-TO-END ANASTOMOSIS REINFORCED BY WRAPPING WITH A PIECE OF FASCIA. (*After Keen.*)

Aneurismectomy with arteriorrhaphy is done in the case of a sac with a narrow opening into the artery (Fig. 249). A piece of the sac may be wrapped about the sutured artery to reinforce the suture if it becomes necessary to resect a portion of the continuity of the artery and do an end-to-end anastomosis (Fig. 250).

Aneurismectomy with transplantation of vein and **transplantation of artery** is possible. The removal of a segment of the artery with the aneurism and filling the gap with a segment of the adjacent vein has been accomplished (page 379). After resecting 3 cm. (1¼ inches) of the axillary artery, the gap of 8 cm. (3 inches) has been filled with a segment of the long saphenous vein from the same patient. The graft should be protected by surrounding it with the muscle or fascia. Transplantation of arteries in animals has been successfully done.

Comments.—The most important preliminary to operations on aneurism is the operation for gradual occlusion of the artery. The methods for performing this will be perfected and undergo many changes. Many methods will be devised; but the principle, enunciated by Halsted, will remain. The

most important modern step in the treatment of aneurism is the operation of endo-aneurysmorrhaphy conceived by Matas. Operation within the sac is so much easier and safer than the older operations of extirpation because it is not carried out among the vessels of the collateral circulation.

In all dealing with aneurisms the accompanying vein had best be preserved.

Aneurismectomy is called for only in cases in which the sac makes dangerous or painful pressure which can not be relieved by endo-aneurism-orrhaphy or other treatment. It should be preceded in most cases by operation to induce gradual obliteration of the artery.

The **spontaneous cure** of aneurism is not uncommon. The clot in the sac becomes deposited layer upon layer until it finally fills the sac and the aneurism is cured. In the case of fusiform non-sacculated aneurism, as the blood-channel becomes narrowed, more and more blood is flowing through the collateral vessels, and by the time the main current is closed the collateral circulation has become adequate. Spontaneous cure is not common enough to be waited for in the place of surgical treatment.

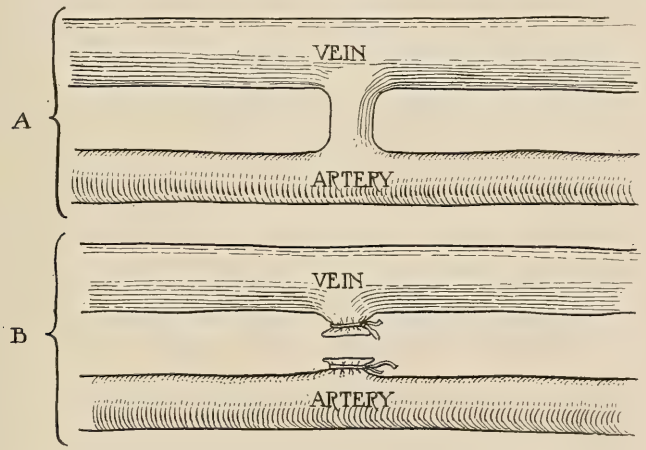


FIG. 251.—ARTERIOVENOUS ANEURISM TREATED BY SIMPLE LIGATION OF CONNECTING CHANNEL.

A, Before operation; *B*, after operation.

Arteriovenous Aneurism.—Many forms of this condition require treatment. There may simply be a communication between vein and artery or an aneurismal sac may exist in connection with one or the other or with both vessels. For therapeutic purposes the main point is the existence of a communication. More or less of an aneurismal swelling exists sooner or later in all cases. At the beginning, if there is not serious hemorrhage or pressure, no operation should be done. The wound which caused the injury should be given careful treatment and the patient's circulation kept at rest by quiet habit. Rest of the parts should be secured by splints if necessary. By delay, the wound heals, exudate is absorbed, the tissues recover from the depression of the injury and collateral circulation is established. Operation should be done during this period if swelling increases, if pressure causes disturbances, if varicosities develop or if the circulation becomes seriously impaired.

1. In rare instances the connection between the two vessels may be cut down upon and found to be a narrow channel which may be ligated (Fig. 251).

2. The sac may be dissected out, a segment of the vein sacrificed and the opening in the artery closed by suture (Fig. 252).

3. The vessels may be ligated above and below the sac and the sac excised (Fig. 253). This is usually an unnecessary amount of traumatism and rarely indicated.

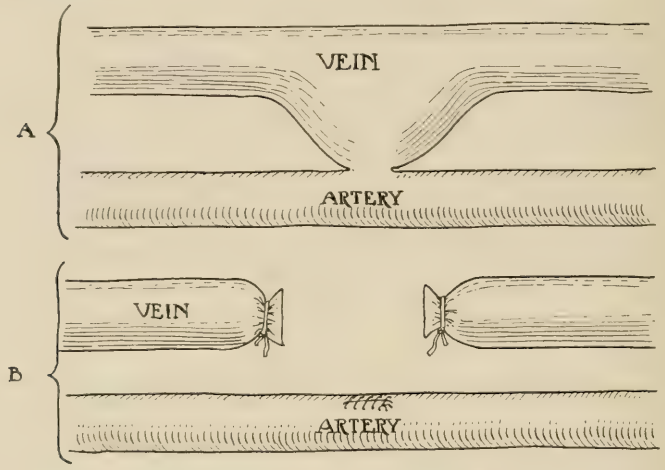


FIG. 252.—ARTERIOVENOUS ANEURISM TREATED BY REMOVING DILATED SEGMENT OF VEIN AND SUTURING OPENING IN ARTERY.

A, Before operation; *B*, after operation.

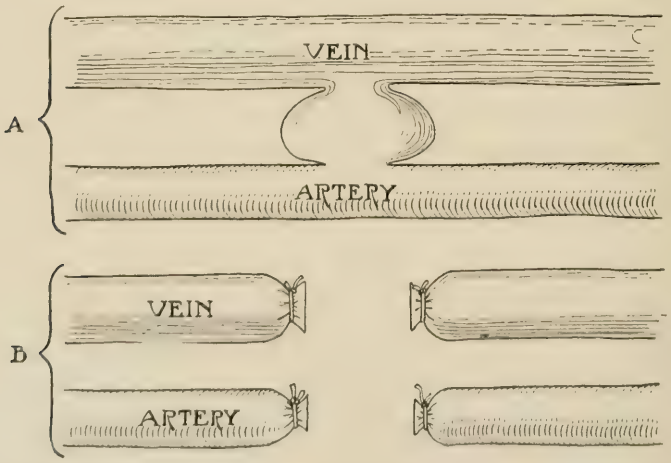


FIG. 253.—ARTERIOVENOUS ANEURISM TREATED BY LIGATING BOTH VESSELS ABOVE AND BELOW THE SAC AND RESECTING THE DISEASED SEGMENT.

A, Before operation; *B*, after operation.

4. The four ligatures may be applied, the sac opened and the two openings into the sac sutured. This quadruple ligation usually constitutes an unnecessary sacrifice of the vessels, and should when possible be substituted by (5).

5. The vessels may be temporarily clamped, the sac incised and the two openings sutured from within the sac (Fig. 254). This is the method of

choice, which was worked out by W. S. Bickham (Annals of Surgery, May, 1904) upon the basis of Matas' suture.

6. The vein may be incised, the opening sutured from within the vein

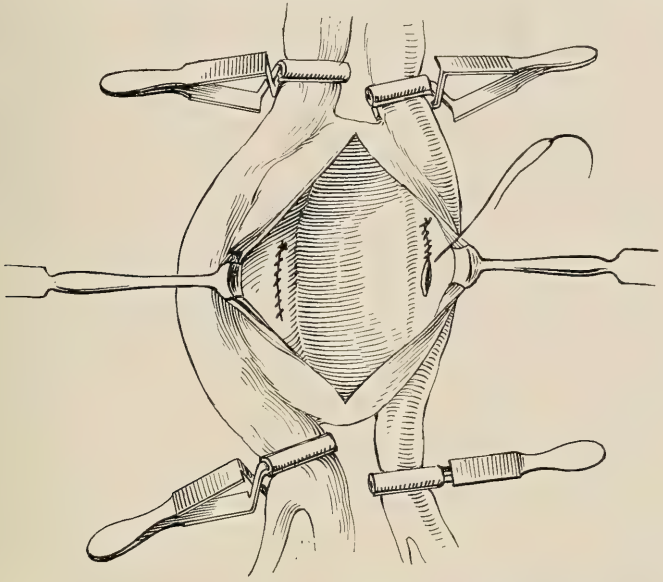


FIG. 254.—ARTERIOVENOUS ANEURISM TREATED BY TEMPORARY CLOSURE OF THE VESSELS, INCISING THE SAC, AND SUTURING THE OPENINGS AS FOR ENDO-ANEURISMORRHAPHY.

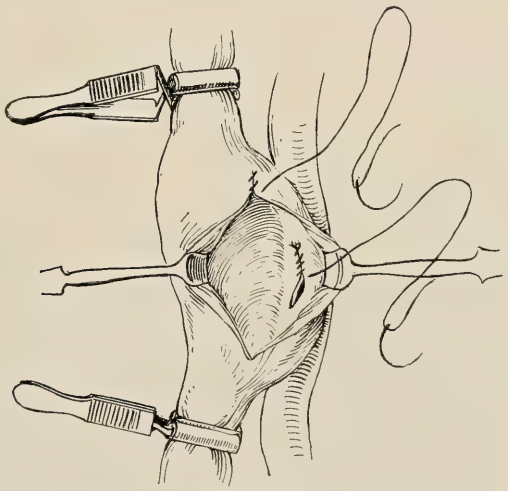


FIG. 255.—ARTERIOVENOUS ANEURISM TREATED BY INCISION OF THE VEIN, AND SUTURE OF THE OPENING FROM WITHIN THE VEIN.

The knots are tied on the outside.

and the wound of the vein closed (Fig. 255). This method is applicable in cases in which the aneurism is developed in the vein rather than the artery.

Matas in *Keen's Surgery* laid down the following principles:

1. Arteriovenous varices (simple aneurismal varices, more especially of

the neck and upper extremity) should not be disturbed or interfered with surgically as long as they do not cause annoying or menacing symptoms or functional disability.

2. Shortly after the injury efforts should be made to favor spontaneous cure by gentle pressure over the anastomosis and on the main artery on the proximal side of the anastomosis or by simple digital compression of the main artery on the proximal side, rest and immobilization.

3. The signs of progressive enlargement of the tumor and other objective or subjective evidences indicate that operative interference is required to arrest its progress, that procedure should be preferred as the method of election which will obliterate the arteriovenous anastomosis without interrupting the continuity of the parent vessels (endo-aneurismorrhaphy) for varicose aneurisms; incision with lateral arteriorrhaphy and phleborrhaphy for the simple aneurismal varices.

4. When the damage done to the vessel is so great that the restoration of the lumen is impossible by any of the methods of intrasaccular suture (restorative and reconstructive endo-aneurismorrhaphy), obliterative aneurismorrhaphy is to be preferred for old well-formed sacs; the intrasaccular ligature on each side of the vascular orifices for recent, thin and ill-defined sacs and traumatic pulsating hematomata.

5. In some aneurismal varices, which are embedded in masses of cicatricial or fibrous tissue too dense to permit of a clean dissection of the vessels entering into the anastomosis, resection of the anastomosis may be necessary, with ligation of the afferent and efferent trunks. In such cases an effort should always be made to restore the continuity of the vessels or of the artery at least by circular or end-to-end suture. If the operator feels himself competent to try transplantation or grafting, he should not sacrifice the satellite vein, even if this is available, but secure a segment of a vein from some other region of the body (saphenous, basilic, cephalic, external jugular).

Aneurism of Special Vessels.—Before considering special aneurisms, the reader is advised to read the above principles of treatment, applicable to aneurisms in general.

Aneurism of the thoracic aorta is amenable to treatment by the general and hygienic measures. Locally, if distinctly sacculated, the methods for producing internal coagulation are applicable. Inserting fine wire and the employment of electricity have effected cures. The natural tendency of the disease is toward the destruction of the patient, and most cases resist treatment and prove fatal. If the aneurism is distinctly sacculated it may be cured by ligating, innominate carotid and subclavian—whichever emanate from the diseased segment. Ligature of the thoracic aorta below the left end of the arch through a posterior thoracotomy has been done. Failure of kidney function was a cause of death.

In a case of ruptured *thoracic aneurism* of the aorta, in which the *x*-ray picture failed to show whether the aneurism was above or below the diaphragm, H. Kümmell (Surg., Gyn. and Obst., xix, 1914) exposed the aorta posteriorly. The fourth to the sixth ribs on the left side were resected close to the spinal column. Care was taken to spare the pleura, but it was pushed forward and the aorta exposed. The sac was found to be above the diaphragm. The aorta was compressed above the sac between the thumb and forefinger of an assistant and at the upper boundary of the pulsating tumor and below at the diaphragm. The sac was then uncovered and the bleeding opening discovered. To secure a good exposure it was necessary to split the diaphragm and expose the abdominal aorta, retroperitoneally.

The sac was trimmed away leaving enough tissue to reconstruct the vessel wall. The opening was closed by continuous suture. Digital pressure was then slightly relaxed and some blood allowed to flow through. As slight leakage appeared, a second row of sutures was applied which gave a perfect closure. Compression was then removed and the blood flowed while the wound cavity was being cleansed. Pulsation in the femorals was full and no leakage appeared. Compression of the aorta had been maintained for about twenty minutes and the operation took an hour. Intravenous ether anesthesia was used and salt solution flowed continuously into the vein. The patient died of exhaustion. The suture held. Kümmell recommended that the line of suture be covered by a broad strip of fascia.

Aneurism of the abdominal aorta is amenable to treatment. The place of choice for occlusion is between the inferior mesenteric artery and the bifurcation of the aorta. Occlusion above or below the aneurism may be done. In desperate cases occlusion above the mesenteric artery may be practised, but the danger of gangrene of the bowel is great. The cases offering the most hope are cases of aneurism of the lower part of the artery or of the common iliac and aorta in which occlusion can be done below the inferior mesenteric artery. Occlusion above the renal arteries results in suppression of kidney function from inadequate pressure.

Suture within the sac has been attempted, but never successfully. It is a justifiable procedure if the blood-stream can be temporarily controlled. Ligation has been tried a number of times but never with success. Patients have survived from a few hours to forty-eight days. The internal tension is so great that the artery can not withstand the pressure. The usual result has been that the walls of the vessel have cut through and fatal hemorrhage has occurred. To obviate this, broad ligation with several rings of ligature has been used. W. W. Keen came the nearest to succeeding with broad ligation. His patient lived forty-eight days, then rupture took place. The success of this operation depends upon the vessel withstanding the great internal pressure and not rupturing, pending the development of a collateral circulation to the pelvis and lower extremities through the branches of the thoracic aorta, subclavian, carotid and axillary arteries. These vessels are capable of providing an adequate collateral circulation if sufficient time for their compensatory dilatation is allowed. This has been observed to be the case when the occlusion of the aorta has been gradually brought about by a tumor. The *sudden* assuming of the burden of the circulation, however, is too much for these smaller vessels.

For this operation to be successful the occlusion of the aorta must be made gradually. This must be done by constricting the aorta until its calibre is reduced one-half or less, using a number of rings of silk, linen, silver wire, or a metal band. The compression should be made in the form of a truncated cone, with the base upward. This constriction may be expected to set up an obliterating endarteritis. If it does not cause occlusion after a few weeks the abdomen may again be opened and the constriction tightened still more. This may be done by tightening the metal band or applying a tighter band of ligatures. Thus the vessel may be reduced to one-fourth or one-eighth of its normal calibre. This may, if necessary, be followed by another operation reducing the vessel to one-eighth or a sixteenth of its normal calibre, or occluding it completely. The number of operations performed should depend upon the progress of occlusion and the development of the collateral circulation. At a final operation the vessel may be tied with several rows of ligature, and the metal band removed. Some day a successful occlusion of this vessel will be accomplished by this principle.

Aneurismorrhaphy may be done in sacculated aneurism after the flow of blood through the diseased vessel had been reduced to the minimum. Abbe has suggested compression of the aorta, longitudinal incision, slipping a glass tube full of salt solution into the lumen of the vessel, and ligating it in place. The current would then be allowed to flow through the tube. Thrombosis would take place gradually permitting dilatation of the collateral vessels.

The solution of the problem lies in the gradual occlusion of the vessel by the metal bands, suggested by Halsted and Matas (page 384), or by some similar device. Such a band should be constructed so as to have a wider opening above than below in order not to cut the vessel with its upper edge (Fig. 256).

The modern surgical treatment of aneurism of the aorta should tend in the direction of *aneurismorrhaphy*. The possibilities of this operation are shown by the operation for suture of the thoracic aorta, described above. This is more easily applied to the abdominal aorta, and is destined to become the operation of the future.

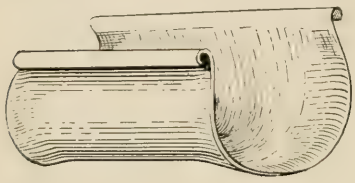


FIG. 256.—METAL BAND FOR COMPRESSION OCCLUSION OF AORTA.

Aneurism of the external iliac artery is amenable to treatment by gradual obliteration or ligation of the artery. This artery may, in case of good collateral supply, be ligated at once. A number of successful operations are reported. Three sites for the ligature or compression are to be recommended: (1) above and below the sac, (2) above, and (3) below. In most cases the most satisfactory treatment is partial occlusion of the artery above or below, gradual establishment of the collateral circulation, and then removal or obliteration of the sac to relieve the pressure of the tumor. The sac full of clot need only be removed if it causes pressure after the aneurism has been cured.

In cases in which the collateral circulation is not efficient and can not be made efficient by temporary occlusion of the artery, restorative or reconstructive endo-aneurismorrhaphy gives the best result. Surgeons of skill and experience may proceed at once with these latter methods and reserve obliterating operations as a last resort. In operations in the sac, clots should be removed from the artery as far as possible.

Aneurismof the internal iliac artery, manifested in *pelvic aneurisms* and *aneurisms of the buttock,* occurring in the vesical, uterine, vaginal, obturator, pudic, sciatic, gluteal, ilio-lumbar, or ilio-sacral arteries, or in the main trunk, because of the peculiar situations in which they occur, should not be mistaken and treated for sarcoma, abscess, or some other unrelated condition. The treatment of any of these aneurisms is entirely the modern treatment. Ligation of the vessel above the sac is the first step. This means either the internal iliac or the branch affected. The sac should then be incised and emptied of clots. All collateral openings should be sutured within the sac, and the sac obliterated by internal suturing. Simple ligation above the tumor is apt to fail because of the collateral circulation which feeds the sac with blood. Aneurisms appearing outside of the pelvis may be treated by double ligation and removal of the sac.

Femoral aneurism is best cured by aneurismorrhaphy, or by gradual obliteration above or below, or by ligation above and below. The treatment is the same as in the external iliac.

Digital and instrumental compression of the common femoral has cured

many of these cases in the preantiseptic days. Later all of the old forms of ligature were effective.

The most satisfactory treatment is bassd upon the newer principles. Intrasaccular suture is used. Restorative or reconstructive operations may often be done, especially if the efficiency of the collateral circulation can not be demonstrated. In the cases not requiring this treatment, gradual obliteration or obliteration by metal band is the operation of choice. Following the operation of obliteration of the lumen of the vessel above the aneurism, the sac should be exposed, opened, cleaned out, and its cavity obliterated by intrasaccular suture.

Popliteal aneurism is the commonest of aneurisms and one of the most amenable to treatment. If aneurismorrhaphy is not done, ligation above and below is the operation of choice. Next in value is ligation at the lowest angle of Scarpa's triangle or in Hunter's canal. Matas has shown results, secured by suture of the sac, which so far surpass all other methods as to make it preëminently the operation of choice.

Aneurism of the innominate artery may rarely be treated by ligation toward the heart. This can be done only when the disease is high up and sacculated. The mortality of this operation is so great that it should be abandoned in all but the exceptional cases in which no other treatment can be applied.

Because of the danger of placing a ligature too near the arch of the aorta, distal ligation is best employed. This involves ligation of the right subclavian and common carotid, and has the widest application. Many successful cases are reported following this operation. The common carotid should be tied first. Cures have been affected by ligating but one of these distal vessels.

Axillary aneurism is most commonly a traumatic lesion, and, therefore, often requires to be treated by exposing the injured vessel and dealing directly with the injury. Usually it requires ligation just above and below the place of rupture. If necessary to secure a good exposure, the high incision parallel and just above the lower border of the pectoralis major muscle should be made and the muscle divided at its insertion as in operation for carcinoma of the breast and axilla. Aneurism, developing slowly as the result of disease, requires aneurismorrhaphy or ligation of the third portion of the subclavian artery. If pulsation recurs in the aneurism, distal ligation of the axillary artery should be done; indeed, if ligation is practised at all the most satisfactory operation is ligation above and below the tumor. The disease has been cured by rest in bed, restricted diet, and compression of the subclavian.

The modern treatment of matured aneurism calls first for the discovery of the efficiency of the collateral circulation by means of temporary compression below or above the disease. If this is satisfactory, permanent occlusion by ligature or metal band should be done, and the sac obliterated by endoaneurismorrhaphy. If the collateral circulation is not efficient, its efficiency should be established by gradual occlusion of the vessel.

Carotid aneurism is amenable to aneurismorrhaphy. Occlusion is the safest operation. If practicable, proximal and distal occlusion and ligation are more certain of effecting a cure. When proximal occlusion can not be done because of the low position of the disease, distal occlusion alone should be done. When double occlusion is done the distal occlusion should be made first to prevent clot being carried to the brain. *Aneurism of the internal carotid* may be cured by occlusion of the common carotid and ligation of the external carotid. This double operation is necessary to secure stasis

between the aneurism and the circle of Willis. Suture and obliteration, but not removal of the sac, may be done. Aneurism of the *external carotid* is treated by the same principle—ligation of internal and external carotids, or of the common carotid and the internal, or of the common carotid and both branches. Ligatures should not be placed on the external carotid alone near the bifurcation because of the great danger of clot being swept into the internal carotid and thence to the brain.

None of these operations of ligation should be done upon the common carotid or the internal carotid without the surgeon first having tested the collateral circulation by means of an occluding band. This may be applied under local anesthesia at the place where ligation is contemplated. The band should be made tight enough to close the vessel but not to injure the intima. If serious disturbances of circulation develop the band may be removed. If the occlusion of the artery is well tolerated it may be allowed to be permanent. Later in the case of a large aneurism, the sac may be opened, after ligation below and above and obliterated by suture within the sac.

Restorative operation may be done in sacculated aneurysm. The reconstructive operation may be applied in cases in which the preliminary occlusion test shows that the collateral circulation is not adequate; but, on account of the danger of failure and of embolism going to the brain, gradual occlusion is to be preferred. In a low-lying aneurism, if distal obliteration of the artery does not result in clot filling the sac, obliterative suture of the sac should be done. The removal of the sac in carotid aneurism is rarely a wise procedure, for in most cases obliteration by suture accomplishes as much with far less risk.

Subclavian aneurism is treated the same as carotid aneurism. Gradual occlusion of the vessel by a temporary band is to be done if it is not known whether the collateral circulation is efficient. If the collateral circulation is efficient then ligation may be done. Obliteration of the sac by suture is to be preferred to removal of the sac. Right subclavian aneurism may be treated by ligation of the right common carotid, followed by ligation of the subclavian distal to the disease. Later, excision of the inner end of the clasicle may be done, and if possible the subclavian ligated on the proximal dive of the aneurism. The object of first ligating the carotid is to prevent cerebral embolism.

Cirsoid Aneurism.—This disease is a form of aneursimal varix in which small vessels are involved. It should not be confused with cavernous angioma, nevus and port-wine stains. It does not demand treatment if it is small and is not growing in size, but usually there is a tendency to grow. If it is increasing in size or area, if it causes pain or annoyance, if it is near important structures, or if its walls are becoming thin, it should receive surgical treatment. The best treatment is excision of the whole diseased collection of vessels. This should be preceded by ligation of all pulsating vessels which can be discovered entering the diseased area. Usually the dilated vessels involve the skin, for which reason, to effect a cure, it is best as a rule to remove the skin also. I have attempted on two occasions to turn back a flap of skin, uncovering the vessels, but should not advise doing so unless the skin is distinctly free from diseased vessels. At the best the operation is a bloody procedure. The excision should go wide of the disease into sound tissue. Multiple mass ligatures placed about the circumference are necessary. It is futile to attempt catching and ligating bleeding points. I have seen three dozen clamps fail to control the bleeding in such a wound which was less than 7 cm. (3 inches) in diameter. Patients have been known to bleed to death during operations for this disease. If the wound resulting

after removal of the affected area is large, a strip of skin may be preserved in the middle to hasten epithelization.

Sometimes the disease is too extensive for treatment by excision. In such cases every possible tributary should be ligated and mass ligatures applied. As much of the disease as possible should be removed. What can not be extirpated may be treated by some of the above described methods for the treatment of aneurism. Compression long continued may produce stasis and coagulation in some of the spaces and agglutination of the walls in others. Electricity may be applied by contact superficially, by needles representing both poles thrust into the disease or by a combination of the two methods. The injection of astringents has produced some cures.

The Occlusion and Ligation of Arteries

The ligation of arteries in their continuity was once a hazardous operation. Modern methods have removed the hazard and placed it among the safe and simple procedures of surgery. The old mortality statistics of these operations are of little modern significance. There are certain general principles which should be observed; and a knowledge of the anatomy of the part is essential. The former dangers of the operation were secondary hemorrhage and gangrene. Aseptic surgery obviates the first danger, and in a large measure prevents the second. The instruments necessary are scalpels, hooked and angular retractors, dissecting forceps, an aneurism needle, ligatures, needles and thread for closing the wound; and the metal bands necessary for occlusion. For special consideration of the Occlusion of Arteries, see page 384. The exposure of the vessel for temporary occlusion and for the use of metal bands is by the same methods as for ligation.

In most operations the patient lies upon the back, the surgeon standing near the side to be operated upon. The position of the vessel is determined. Usually it can be felt through the skin. If the surgeon desires, its position may be marked with a line of stain. This should not be necessary. The incision should be made over the vessel and parallel to it, and should be long enough freely to expose the vessel. It should be placed preferably at such a position as to avoid the branches of the artery. Small veins lying over the vessel should be ligated or retracted. Overlying muscles should be retracted or penetrated by blunt dissection.

The artery is first discovered by palpation. It feels like a piece of soft rubber tubing. When compressed, a large artery feels like a flat band with elevated rounded edges. Veins are scarcely palpable. The accompanying veins are larger than the artery, easily compressible, and swell up on the distal side of the compression. The artery pulsates unless constricted; it is of a pale red or reddish-yellow tint and regular in outline. The larger arteries are lighter in color. The veins are irregular in outline and of a purple or dark red color. The nerve feels like a round cord, scarcely compressible, and of a light grayish-pink color. Tendons are hard and covered with shiny synovial membrane. They can be identified by moving the muscle. The arteries of the upper extremities and the arteries below the knee each have two venæ comites. The arteries of the head and neck, with the exception of the lingual, each have one attending vein. The lingual and most of the smaller arteries of the trunk each have two venæ comites. These accompanying veins communicate with one another by short branches passing across the artery. It should always be remembered that variations from the typical anatomy of arteries are common.

As the dissection reaches the sheath of the vessel the sheath should be picked up lightly with the forceps (Fig. 257), lifted away from the artery and incised. Care will prompt cutting the sheath, not with the edge of the scalpel directed toward the artery, but in the direction of a plane between the forceps and the vessel. The artery is thus exposed lying in its loose cellular bed. The blunt aneurism needle (Fig. 258) is used to free it from the sheath and is passed around the artery, lifting it slightly out of its bed. The needle should be passed in the direction away from the vein to avoid injury to the latter (Fig. 259). It is better to include small tributary veins in the ligature than to take the pains to avoid them. Care should be taken to avoid the nerve. After passing the needle, it is threaded with the ligature and withdrawn. In the case of deep vessels the ligature may be inserted in the eye of the needle before it is passed. In passing the needle around an artery the greatest gentleness should be used. The employment of force to overcome obstructions invites disaster.

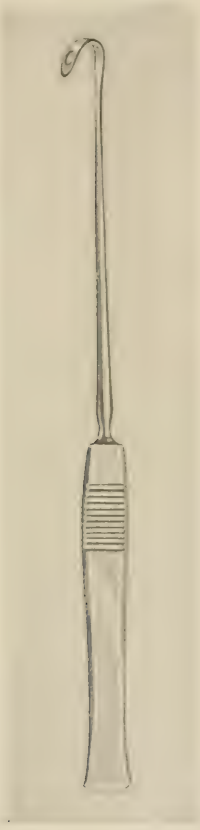


Fig. 258.—Aneurism Needle for Passing Ligature around Vessel.

The best material for ligating vessels is catgut. *Chromic gut* should be used for the larger arteries. The ligature should be tied at right angles to the vessel. Undue traction upon the vessel should not be made. The tips of the

Fig 257.—Opening Sheath to Expose and Ligate Artery.

Forceps lift up sheath alone. Incision of sheath should be carefully made to avoid injury to artery or vein.

index fingers should pass down each side to the knot (Fig. 260). It is not necessary to tie so tightly as to rupture the inner and middle coats of the artery. Firm occlusion of the vessel is all that is needed; and the inner coat will become adherent. A square knot should be tied, with an extra turn in the first half for security. In tying large vessels, such as the innominate and common iliac, two or more ligatures side by side give a more secure result. The object is to secure the effect of a band rather than that of a single ligature (Fig. 261). In tying small vessels, it is often more convenient to pick up the artery with two small clamps, cut between and ligate each end. Having tied the vessel the ends of the ligature should be cut, not too short and the wound closed, usually by a running suture of catgut

for the fascia and a subcuticular suture for the skin. If there is a possibility of gangrene the whole limb should have been rendered clean before the operation and swathed in aseptic gauze and cotton.

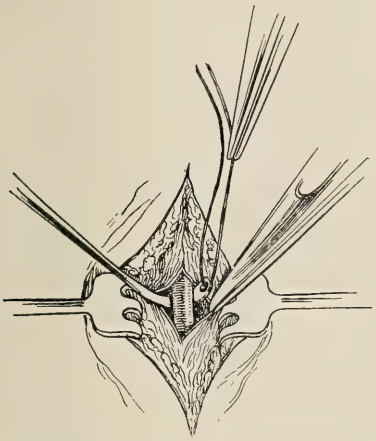


FIG. 259.—PASSING ANEURISM NEEDLE WITH LIGATURE AROUND ARTERY.

Loop of ligature is picked up at end of needle and drawn through with forceps.

FIG. 260.—TYING ARTERY.

The first half of the knot should be two turns, and the last half should complete the surgeon's knot.

Innominate Artery.—The patient is placed supine with the shoulders slightly raised and the head thrown back. An incision is made along the anterior margin of the sternomastoid muscle, ending below at the sternum (Fig. 262). It should be about 8 cm. (3½ inches) long. This should be joined by a second shorter incision along the upper border of the right clavicle. The flap of skin and fascia should be dissected up to expose the muscles. The sternal origin and part of the clavicular origin of the sternomastoid should be divided. The sternohyoid and sternothyroid muscles should also be divided at their origin (Fig. 263). The inferior thyroid veins should be retracted or ligated in two places and divided. The deep cervical fascia should be divided and the common carotid artery exposed. The carotid is followed downward to the innominate, which is exposed by retracting downward the left innominate vein. The right phrenic and pneumogastric nerves and the right innominate vein lie close to the vessel. The needle should be passed close to the artery on the right side to avoid these structures. By keeping close to the artery, the pleura and trachea are avoided (Fig. 264).

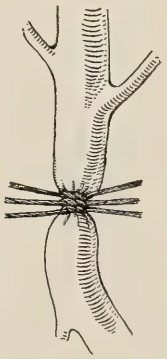


FIG. 261.—SHOWING FORM OF LIGATURE USED IN TYING LARGE ARTERIES.

These ligatures, as the next step, should all be tied together.

By resecting a portion of the sternum the approach to the vessel is facilitated. When this is done the incision is carried down in front of the sternomastoid muscle and down the middle of the manubrium. The muscles are divided at their origin from the bone. A flat retractor is

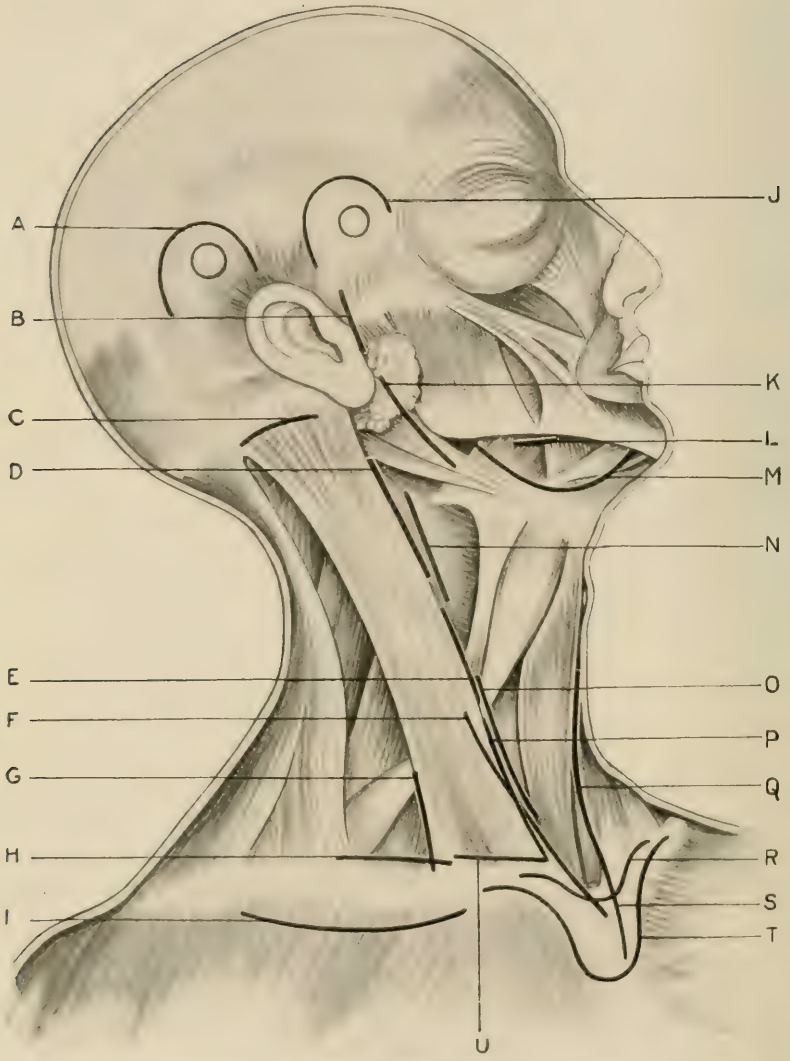


FIG. 262.—INCISIONS FOR LIGATION OF ARTERIES OF HEAD AND NECK.

A, Posterior branch of middle meningeal exposed by trephine opening; *B*, temporal above zygoma; *C*, occipital at mastoid process; *D*, internal carotid near origin; *E*, common carotid above omohyoid; *F*, innominate by oblique incision; *G*, transversalis colli and suprascapular at outer margin of sternomastoid; *H*, third part of subclavian; *I*, first part of axillary by curved incision below clavicle; *J*, anterior branch of middle meningeal through trephine opening; *K*, external carotid above digastric; *L*, facial at border of jaw; *M*, lingual beneath hyoglossus; *N*, external carotid below digastric; *O*, common carotid below omohyoid; *P*, *U*, innominate by angular incision; *Q*, *S*, innominate; *R*, innominate by bony resection; *T*, innominate by bony resection or by splitting manubrium. (*After Bickham*).

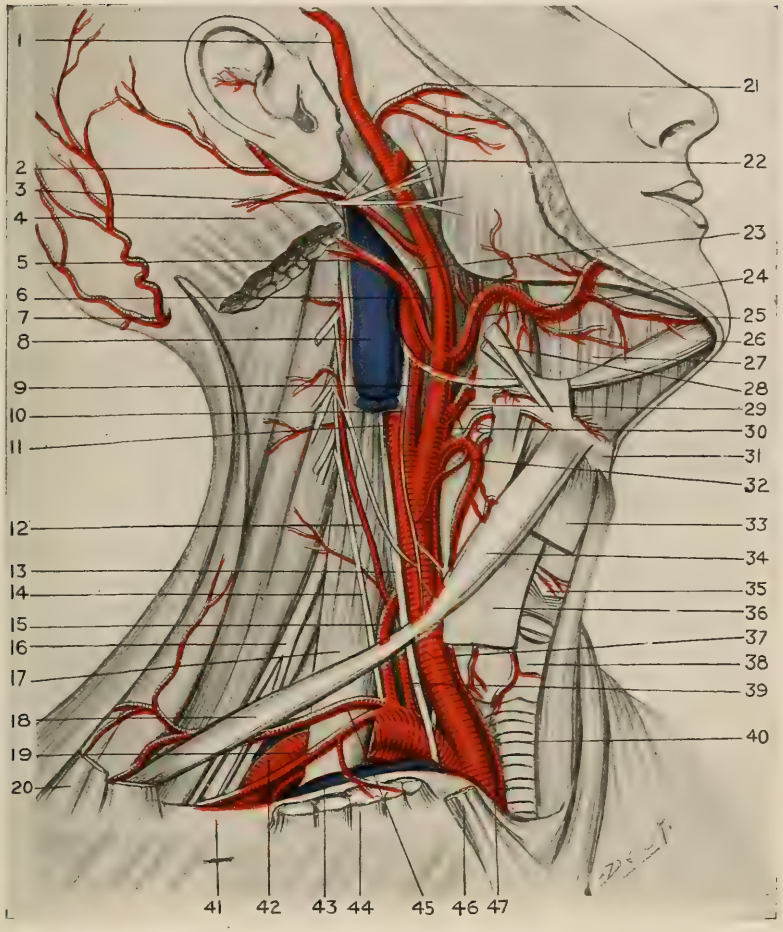


FIG. 263.—ANATOMY OF NECK.

1, Temporal artery; 2, posterior auricular artery; 3, facial nerve; 4, sternomastoid muscle; 5, occipital artery; 6, external carotid artery; 7, occipital branch of vertebral artery; 8, internal jugular vein; 10, descending branch of ninth nerve; 11, internal carotid artery; 12, ascending cervical branch of inferior thyroid artery; 13, vagus nerve; 14, phrenic nerve; 15, inferior thyroid artery; 16, brachial plexus; 17, scalenus anticus muscle; 18, omohyoid muscle (posterior belly); 19, suprascapular artery; 20, trapezius muscle; 21, transverse facial artery; 22, internal maxillary artery; 23, stylopharyngeus muscle; 24, facial artery; 25, submental artery; 26, digastric muscle; 27, mylohyoid muscle; 28, stylohyoid muscle; 29, lingual artery; 30, external carotid artery; 31, hyoid bone; 32, superior thyroid artery; 33, sternohyoid muscle; 34, omohyoid muscle (anterior belly); 35, cricothyroid artery; 36, sternothyroid muscle; 37, common carotid artery; 38, thyroid gland; 39, vertebral artery; 40, trachea; 41, clavicle; 42, subclavian artery; 43, subclavian vein; 44, sternomastoid muscle; 45, transversalis colli artery; 46, sternal head of sternomastoid muscle; 47, innominate artery. (*After Gray.*)

slipped behind the bone to protect the vessels and the upper and outer portion of the manubrium with the sternoclavicular articulation and the attachment of the first rib are cut away with bone-cutting forceps. The operation is then proceeded with as above.

The *indications* for the operation are aneurism of the lower part of the common carotid, of the first part of the right subclavian, and of the arch of the aorta.

Common Carotid Artery.—The patient is placed on the back with a sand bag under the shoulders to make the lower part of the neck prominent. The head is thrown back and the face turned to the opposite side. The surgeon stands upon the side to be operated upon. The common carotid lies in a

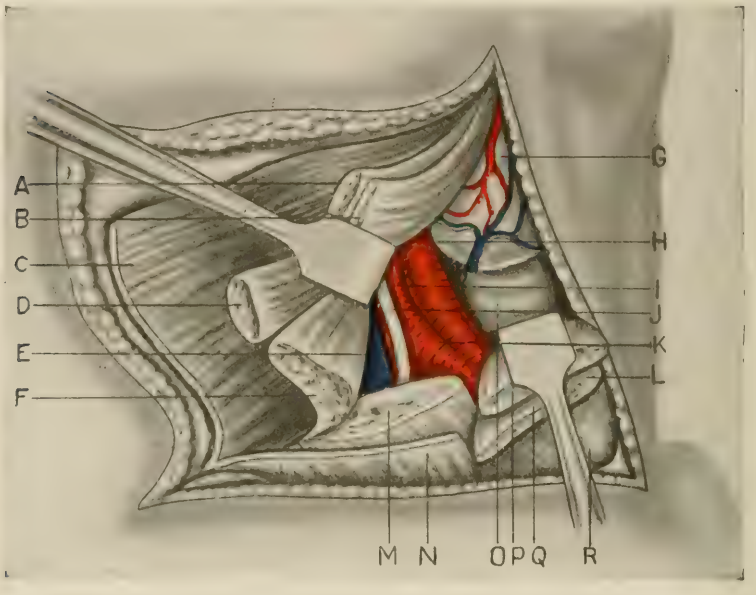


FIG. 264.—INNOMINATE ARTERY EXPOSED BY AN ANGULAR INCISION; ALSO RIGHT COMMON CAROTID, AND THE VERTEBRAL ARTERY NEAR ITS ORIGIN.

A, Sternohyoid muscle; *B*, sternothyroid; *C*, platysma; *D*, sternomastoid; *E*, internal jugular vein; *F*, sternomastoid; *G*, thyroid gland; *H*, common carotid artery; *I*, vertebral artery; *J*, pneumogastric nerve; *K*, innominate artery dividing into common carotid and subclavian; *L*, *Q*, sternohyoid; *M*, sternomastoid; *N*, platysma; *O*, trachea; *P*, sternothyroid; *R*, right sternoclavicular articulation. (*After Bickham.*)

line drawn from a point midway between the angle of the jaw and the tip of the mastoid process downward to the sternoclavicular joint. It bifurcates into external and internal carotid at the level of the upper border of the thyroid cartilage.

The common carotid artery is contained in a sheath derived from the deep cervical fascia, which also contains the internal jugular vein, on the outer side of the artery, and the pneumogastric nerve, posteriorly and between the two vessels. The anterior edge of the sternomastoid muscle lies over the vessel. In the lower part of the neck the carotid is deeply placed, being covered by the platysma, sternomastoid, sternohyoid and sternothyroid muscles. It is crossed diagonally by the omohyoid muscle opposite the cricoid cartilage. In its upper part, above the omohyoid muscle, it is quite superficial, being covered by the inner margin of the sternomastoid muscle, and is contained in the *superior carotid triangle.*

This triangle is bounded above by the posterior belly of the digastric, behind by the sternomastoid, and in front by the anterior belly of the omohyoid muscle. In this triangle

the artery is crossed from within outward by the sternomastoid artery and by the superior thyroid veins which empty into the internal jugular. It is crossed by the trunks of the descendens noni nerve which are joined by branches from the cervical nerves. The middle thyroid vein crosses the artery about its middle. The anterior jugular vein crosses in the lower part of the neck. The vessel lies upon the muscles of the spine. The sympathetic nerve is behind it. At its lower part the recurrent laryngeal nerve and the inferior thyroid artery cross behind it. It is in relation internally with the trachea and thyroid gland, the recurrent laryngeal nerve and the inferior thyroid artery passing from behind internal to it. The upper part of the artery is in relation with the larynx and pharynx. On its outer side are the internal jugular veins and the pneumogastric nerve. On the left side in the lower part of the neck the internal jugular vein often overlaps the artery. The *carotid tubercle* is a tubercle on the transverse process of the sixth cervical vertebra. It is easily felt about 6 cm. (2½ inches) above the clavicle. The carotid artery lies directly in front of it. Just below the tubercle the vertebral artery passes through its foramen and the inferior thyroid curves forward. The tubercle is about opposite the point where the omohyoid muscle crosses the carotid.

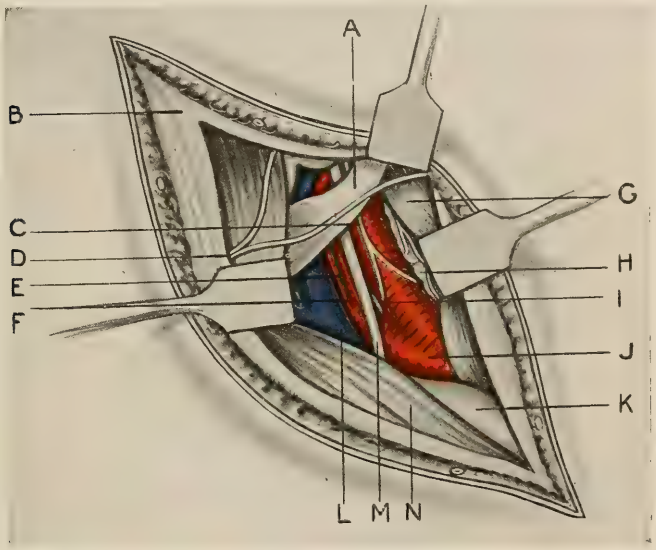


FIG. 264A.—RIGHT COMMON CAROTID ARTERY EXPOSED BELOW OMOHYOID BY OBLIQUE INCISION; ALSO INNOMINATE, VERTEBRAL NEAR ORIGIN, AND INFERIOR THYROID NEAR ORIGIN.

A, Omohyoid muscle; *B*, platysma covered by fascia; *C*, branches of nerve from communicans and descendens hypoglossi; *D*, superficial cervical nerves; *E*, inferior thyroid artery; *F*, vertebral artery; *G*, sternohyoid muscle; *H*, thyroid gland; *I*, recurrent laryngeal nerve; *J*, innominate artery dividing into common carotid and subclavian; *K*, sternum; *L*, right innominate vein with subclavian and internal jugular; *M*, pneumogastric nerve; *N*, sternomastoid muscle. (*After Bickham.*)

To ligate the carotid below the omohyoid in the *inferior carotid triangle* (Fig. 264), an incision 7 or 8 cm. (3 inches) long is made, from the cricoid cartilage to the sternoclavicular joint along the anterior border of the sternomastoid muscle. The superficial veins are tied. The deep fascia is opened, the sternomastoid retracted outward, the sternohyoid and sternothyroid are retracted inward, and the vessel felt. If the vessel can not be located the carotid tubercle can be found and used as a guide. The omohyoid muscle is drawn upward, the sheath of the vessel opened, and the aneurism needle passed from without inward avoiding the internal jugular vein and pneumogastric nerve.

To ligate in the *superior carotid triangle* (Fig. 265), which is the easier and preferable operation, an incision 7 or 8 cm. (3 inches) long is made along the line of the artery, the middle of the incision being opposite the cricoid cartilage. By care the external jugular vein may be avoided. The deep fascia is opened, and the sternomastoid muscle retracted outward. The vessel is easily felt. The omohyoid is retracted downward. Often the descendens noni nerve is seen lying outside of the sheath in front of the artery. The sheath is opened and the needle passed from without inward to avoid the vein and nerve. This same incision placed a little higher permits ligation of the internal and external carotid and the lower branches of

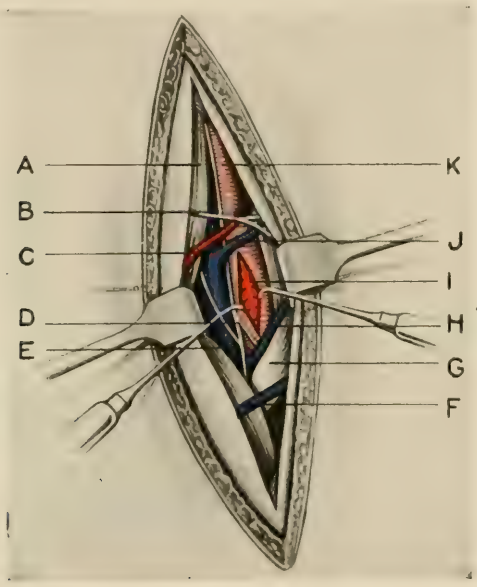


FIG 265.—RIGHT COMMON CAROTID ARTERY EXPOSED ABOVE OMOHYOID.

A, Sternomastoid muscle retracted outward; *B*, transversalis colli nerve; *C*, sternol mastoid artery; *D*, descendens noni nerve lying on sheath of common carotid; *E*, internajugular vein; *F*, communicating vein; *G*, omohyoid muscle; *H*, inferior thyroid vein; *I*, common carotid artery seen through retracted incision in its sheath; *J*, superior thyroid vein; *K*, common carotid covered by sheath. (*After Bickham.*)

the latter. Ligation of the common carotid is accompanied with but little immediate danger, but cerebral softening is observed to follow sooner or later in about 30 per cent. of cases.

It is possible that the dangers to the brain, due to disturbance of circulation, may be prevented by "slow ligation." This may be done by shutting off the circulation in stages. Or it is possible that the same effect may be secured by tying the internal jugular vein at the same time.

The *indications* for the operation are wounds of the vessel or its large branches; aneurism of the vessel or its main divisions, aneurism of the innominate artery, aneurism of the orbit; to control hemorrhage in extensive operations; and in wounds of the internal jugular in order to find and close the bleeding point. In these latter cases temporary occlusion of the common carotid is of much service.

External Carotid Artery.—The patient is placed in the same position and the incision is in the same line as for ligation of the common carotid. The incision should be 7 or 8 cm. (3 inches) long and should extend from the angle of the jaw, along in front of the sternomastoid muscle, to a point opposite the middle of the thyroid cartilage. Safety lies in keeping well toward the median line. The sternomastoid muscle is retracted outward. The artery begins at a point opposite the upper border of the thyroid cartilage. Just above the beginning of the artery is the hyoid bone. The hypoglossal nerve crosses the artery just above the level of the hyoid bone. Above

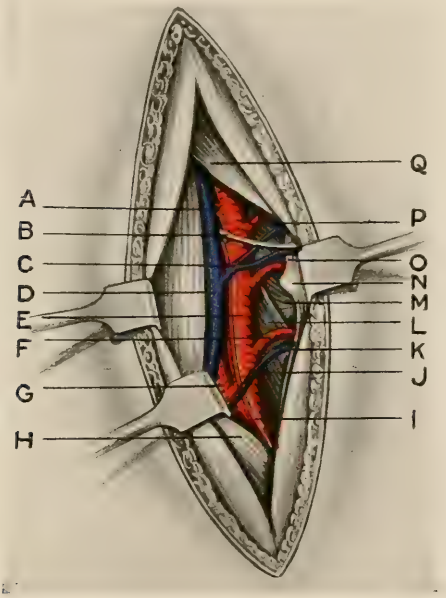


FIG. 266.—RIGHT EXTERNAL CAROTID ARTERY EXPOSED BELOW DIGASTRIC; ALSO INTERNAL CAROTID, SUPERIOR THYROID, LINGUAL, FACIAL AND OCCIPITAL.

A, Occipital artery at its origin; *B*, hypoglossal nerve; *C*, lingual and facial veins emptying into internal jugular; *D*, internal jugular vein; *E*, external carotid; *F*, superior thyroid artery; *G*, internal carotid; *H*, sternomastoid muscle retracted outward; *I*, descendens noni nerve; *J*, superior thyroid vein; *K*, thyrohyoid muscle; *L*, inferior constrictor of pharynx; *M*, middle constrictor muscle; *N*, tip of great cornu of hyoid bone; *O*, hyoglossus muscle with lingual artery disappearing under it; *P*, facial artery; *Q*, posterior belly of digastric muscle. (*After Bickham.*)

this, the posterior belly of the digastric muscle crosses the vessel. The sheath is opened below the level of the hyoid bone. In order to distinguish the external from the internal carotid it will be observed that the external takes a slightly curved course upward and forward and becomes more superficial than the internal. It gives off branches from the beginning. The place of election for ligation is between the superior thyroid and lingual arteries (Fig. 266).

The *indications* for ligation are wounds, uncontrolled bleeding from the tonsil, to starve malignant growths, to check meningeal bleeding, and aneurism. Temporary ligation or occlusion is of much value in operations about the head. I have habitually practised it as a preliminary to excision of the upper jaw.

Internal Carotid Artery.—The line in which this vessel lies is parallel with that of the external carotid and 1.25 cm. (½ inch) external to it. The artery begins at the upper border of the thyroid cartilage. At its beginning it lies posterior and internal to the external carotid. The lower 2.5 cm. (1 inch) of the vessel are accessible for ligation. The internal jugular vein is in the same sheath and lies external to the artery. The pneumogastric nerve lies between the two but posteriorly. Behind the artery lie the superior cervical ganglion and the superior laryngeal nerve. The incision for exposing the artery is 7 or 8 cm. (3 inches) long and 1.25 cm. (½ inch) external to that of the external carotid. The sternomastoid muscle is drawn outward, and the external carotid artery is retracted inward. The vessel is recognized by its more posterior and external position and by the absence of branches (Fig. 266). The needle should be passed from without inward. The dangers of cerebral changes are nearly as great after ligation of this artery as after ligation of the common carotid.

The *indications* for this operation are, in wounds of the artery, aneurism of the artery, and aneurism of the orbital artery.

Inferior Thyroid Artery.—This vessel is a branch of the thyroid axis, coming from the first portion of the subclavian artery. It is ligated through the same incision as that made for ligation of the common carotid below the omohyoid. The vessel passes upward and inward behind the internal jugular, the pneumogastric nerve and the carotid artery to reach the thyroid gland. On the left side it lies on the esophagus, and the thoracic duct is at first posterior to it and then arches over it to enter the left subclavian vein. The phrenic nerve lies close to the outer side of the artery below. The recurrent laryngeal nerve lies behind the artery. After retracting outward the sternomastoid muscle, the carotid and jugular are also retracted outward. The inferior thyroid is found to cross behind the carotid just below the carotid tubercle. The ligature should be applied with care to avoid the recurrent laryngeal nerve.

When ligating this vessel for goiter, it may be approached by a transverse incision, 4 or 5 cm. long, over the tendon of the omohyoid muscle. The thyroid gland is retracted inward and the carotid artery outward (Fig. 264*A*).

Vertebral Artery.—This vessel is the largest branch of the subclavian. It ascends in the neck from the first portion of the subclavian, lying behind the internal jugular vein, the inferior thyroid artery and the carotid. It lies upon the vertebral muscles posteriorly, enters the foramen in the transverse process of the sixth cervical vertebra, passes through the foramina in the vertebræ above, enters the skull, joins with its fellow of the opposite side and enters the circle of Willis (Fig. 264*A*).

It is best exposed through the same incision as that used for ligation of the common carotid. That artery with the phrenic nerve and internal jugular vein should be retracted outward with a blunt retractor. The transverse process of the sixth cervical vertebra is felt about 1 cm. above the cricoid cartilage of the larynx. The longus colli muscle is divided transversely just below this transverse process, and the artery is exposed. Unless an injury below this demands it, there is no advantage in tying the vessel lower, in a more dangerous area, because it gives off no branches below this point.

The vesssel may also be exposed by placing the patient as for ligation of the carotid, with the shoulder thrown back, and an incision 10 cm. (4 inches) long made along the outer border of the sternomastoid muscle in the hollow in front of the scalenus anticus. This incision should end below about 1.25 cm. (½ inch) above the clavicle. The external jugular vein is retracted inward with the sternomastoid muscle. A blunt separation of the con-

nective tissue is now made posterior to the internal jugular, vagus, and carotid. Exposing the front of the scalenus anticus muscle, the phrenic nerve and the transverse cervical artery come into view. The subclavian artery is in the lower part of the wound; the pleura lies internally and below. The aponeurosis, passing in front of the scalenus anticus to the longus colli and the cartoid tubercle, should be divided about 2.5 cm. (1 inch) below the tubercle along the outer border of the longus colli muscle. The artery is seen lying in the space between the two muscles, usually covered by its vein. In ligating it care should be taken to see that the phrenic nerve is not damaged. Some branches of the inferior cervical ganglion are apt to be in-

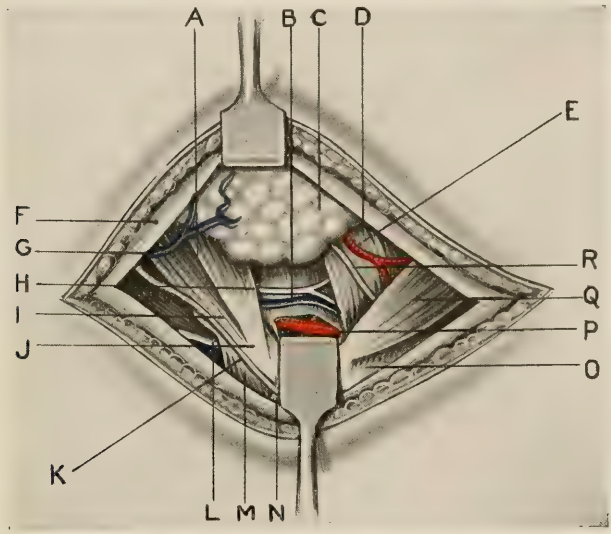


FIG. 267.—RIGHT LINGUAL ARTERY EXPOSED BENEATH HYOGLOSSUS.

A, Space between stylohyoid and digastric; *B*, ranine vein; *C*, submaxillary gland; *D*, mylohyoid muscle; *E*, submental artery; *F*, platysma covered by fascia; *G*, branch of temporomaxillary vein; *H*, hypoglossal nerve; *I*, posterior belly of digastric; *J*, stylohyoid; *K*, transverse cervical nerve; *L*, superior laryngeal nerve and vessels; *M*, thyrohyoid; *N*, omohyoid beneath retractor; *O*, mylohyoid; *P*, lingual artery through incision in hyoglossus muscle; *Q*, anterior belly of digastric; *R*, branch of anterior jugular vein. (*After Bickham.*)

cluded in the ligature, causing the pupil to contract. The thoracic duct curves round the vessel below on the left side. This is a much more difficult and dangerous operation than the first.

The *indications* for this ligation are wounds of the vessel.

Superior Thyroid Artery.—The ligation of this vessel is accomplished through the incision used for the external carotid. The artery is not deep, and is easily found passing forward from the lower part of the anterior aspect of the external carotid just below the level of the hyoid bone. It immediately curves downward to the thyroid gland, passing beneath the omohyoid, sternohyoid and sternothyroid muscles (Fig. 266).

Lingual Artery (Fig. 266 and 267).—The lingual artery arises from the external carotid about opposite the cornu of the hyoid bone, and plunges beneath the digastric and stylohyoid muscles and upon reaching the posterior margin of the hyoglossus muscle passes under the muscle and forward to the tongue. Ligation may be done at the beginning of the artery just below the digastric through the incision used to expose the external carotid, or it

may be done in the submaxillary triangle. The latter operation is to be preferred. The head is thrown back and rotated away. An incision is made from the angle of the jaw downward and forward in the direction of the posterior belly of the digastric muscle to the hyoid bone and thence curving upward and forward to the symphysis of the lower jaw. This cut passes through the skin, platysma and superficial layer of the deep fascia. The submaxillary gland is retracted upward. The digastric muscle and hypoglossal nerve are exposed. The mylohyoid muscle may be found encroaching upon the triangle and require to be retracted forward. The lower part of the digastric triangle having been well exposed, the hyoglossus muscle is divided transversely or its fibres separated close to the hyoid bone. The lingual artery will be discovered running beneath the muscle forward and upward in a direction about parallel to that of the hypoglossal nerve, the muscle separating the two. Here it is tied.

The *indications* for operation are, to secure anemia preliminary to excision of the tongue, to restrain bleeding from the tongue, and for wounds.

Facial Artery.—The facial artery leaves the external carotid just above the origin of the lingual; it passes upward, outward and forward over the body of the lower jaw about an inch in front of the angle of the jaw. It may be tied near its origin through the incision used for exposing the external carotid, but it is most accessible after it becomes superficial. It courses beneath the digastric and stylohyoid muscles and grooves the posterior and upper border of the submaxillary gland. A short incision is made just below the border of the body of the lower jaw and parallel to the bone. The centre of the incision should be over the artery, which is at the anterior border of the masseter muscle. The artery is easily felt and ligated. The vein lies posterior to the artery (Figs. 266 and 268).

Temporal Artery.—The temporal is the continuation of the external carotid. It lies midway between the condyle of the jaw and the tragus of the ear. It begins in the parotid gland just above the point where the carotid is crossed by the facial nerve. The vessel passes up over the zygoma, 5 cm. (2 inches) above which it divides into anterior and posterior temporal. The vessel is best ligated as it crosses the zygoma through an incision about 1.25 cm. (½ inch) long parallel to its course (Fig. 269).

Occipital Artery.—This vessel originates from the back of the external carotid opposite the origin of the facial. It courses upward and backward beneath the digastric, stylohyoid and sternomastoid muscles. It crosses the internal carotid artery and the jugular vein, and passes between the mastoid process and the atlas, grooves the temporal bone, and ascends over the back of the head. It may be ligated near its origin through the same incision as is used to reach the external carotid. The hypoglossal nerve crosses the origin of the artery. To ligate back of the mastoid process, the head is turned to one side, and an incision is carried from the tip of the mastoid process backward and upward half way to the occipital protuberance. The incision should divide the skin, aponeurosis of the sternomastoid muscle, and the splenius capitus muscle. The parts are to be widely retracted and the artery discovered lying between the mastoid process and the atlas where it may be ligated (Fig. 263).

Posterior Auricular Artery.—This artery arises from the external carotid in the parotid gland about midway between the mastoid process and the angle of the jaw, and passes backward and upward between the mastoid process and the external auditory meatus. It is crossed by the facial nerve. It is best ligated above the nerve by an incision over its course behind the ear. The nerve is on a level with the lower limit of the lobe of the ear (Fig. 263).

Middle Meningeal Artery.—See Intracranial Operations, Vol. II.

Subclavian Artery.—The subclavian artery arises on the right side from the innominate artery opposite the right sternoclavicular articulation; on the

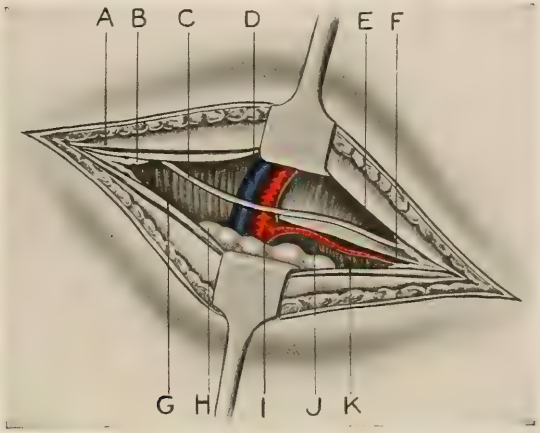


FIG. 268.—RIGHT FACIAL ARTERY EXPOSED AT BORDER OF LOWER JAW.

A, Superficial layer of deep fascia, overlying platysma and depressor anguli oris; *B*, deep cervical fascia; *C*, supramaxillary nerve; *D*, facial vein; *F*, border of lower jaw; *G*, masseter muscle; *H*, submaxillary gland; *I*, facial artery; *J*, submental artery; *K*, mylohyoid muscle. (*After Bickham.*)

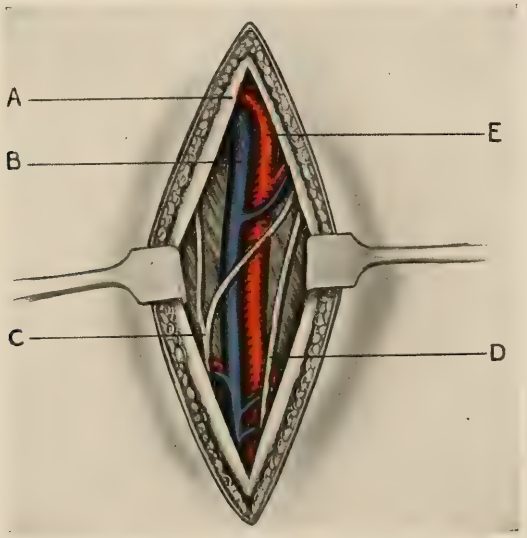


FIG. 269.—RIGHT TEMPORAL ARTERY EXPOSED ABOVE ZYGOMA.

A, Temporal fascia overlying muscle and vessels; *B*, temporal vein; *C*, temporal branches of auriculo-temporal nerve; *D*, branch of temporal division of facial nerve; *E*, temporal artery. (*After Bickham.*)

left side it arises from the arch of the aorta. The vessel arches outward over the first rib behind and below the clavicle and becomes the axillary artery as it enters the axilla.

For convenience of description each subclavian artery is divided into three parts. The first parts are different in the two vessels. The second and third parts correspond on the two sides. The first part of each ends at the inner margin of the scalenus anticus muscle and the inner margin of the first rib.

On the *right side* the first part ascends in the neck a little above the clavicle and lies behind the bone and the muscles attached to it. It is crossed by the internal jugular and vertebral veins, and by the vagus, the phrenic and the cardiac branches of the sympathetic nerves. The pleura is below it. Behind are the spinal muscles, the transverse process of the seventh cervical vertebra, the recurrent laryngeal, and the sympathetic nerves. The subclavian vein lies below and in front of the artery just behind the clavicle.

On the *left side* the first part begins opposite the third dorsal vertebra. It is longer than on the right side, situated more deeply in the chest, and ascends almost vertically. In front is the pleura, the vagus, phrenic and cardiac nerves, the left cartoid artery, left internal jugular and innominate veins and the sternal attachment of the neck muscles. Behind is the esophagus, thoracic duct, sympathetic ganglia and spinal muscles. The esophagus, thoracic duct and trachea are on the inner side and the pleura on the outer side.

The *second portion* of the subclavian lies on the first rib behind the scalenus anticus muscle, and forms the highest part of the arch. In front are the muscle, phrenic nerve and subclavian vein; behind are the pleura and middle scalenus muscle; above is the brachial plexus; and below are the pleura and first rib.

The *third portion* of the artery courses outward and downward from the outer margin of the scalenus anticus to the lower border of the first rib. Here it becomes the axillary artery. In front are the external jugular, suprascapular transverse and subclavian cervical veins; behind is the middle scalenus muscle; above is the brachial plexus; and below is the first rib. The third portion gives off no branches. The scalenus anticus is between the vein and artery.

The vessel is usually ligated in the *third portion*. The first and second portions are rarely ligated. For ligation of the third portion the patient lies on the back with the shoulders thrown back by a sand bag between them. The head is rotated toward the opposite side. The arm on the side to be operated on should be drawn upward to raise the shoulder and the clavicle as high as possible. The ease of the operation depends on this procedure. The arm is used as a tractor for this purpose. The object is to gain as much space below the clavicle as possible. The incision is made transversely and just below the middle third of the clavicle. It should be about 8 cm. (3 inches) long. The pectoralis major and some fibers of the deltoid are divided. From without inward are easily discovered the nerves, artery and vein. The nerves are first exposed. They constitute the brachial plexus, and are in a bundle which is not disturbed. The artery lies about 1 cm. (⅜ inch) internal to the nerves. The vein need not come into view. The sheath of the artery should be opened and the needle passed from within outward, close to the artery, and thus avoiding vein, pleura, and brachial plexus. The muscles are sutured back in place.

The more common and more difficult and dangerous method consists in the approach above the clavicle. The shoulder should be drawn down strongly by an assistant or the forearm held under the patient's buttock. The surgeon stands facing toward the patient's head. The skin is slid down over the clavicle about 1.25 cm. (½ inch) and an incision is carried transversely from the anterior border of the trapezius to the posterior border of the sternomastoid muscle. The center of the incision is about 2.5 cm. (1 inch) internal to the central point on the superior border of the clavicle. By thus drawing down the skin the external jugular vein is avoided and the subclavian triangle is opened ½ inch above the clavicle. The incision is about 8 cm. (3 inches) long, and divides the platysma and some superficial veins. The areolar tissue is separated, the deep fascia is opened. The external jugular vein appears in the inner end of the wound: it may be retracted or divided between two ligatures. The outer edge of the scalenus anticus muscle is found and followed down to the artery. The omohyoid muscle is retracted upward. The finger, passed down the outer edge of the scalenus

anticus, reaches the first rib. The vein lies in front and the artery behind the two being separated by the muscle. The tubercle to which the muscle is attached on the inner edge of the rib can be felt. The artery can be felt lying upon the rib. The lower cord of the brachial plexus must be identified and lifted upward. The vein, lying on a lower level than the artery, may be pressed forward and downward with the finger as the aneurism needle is passed. The accident of tying the cord of the brachial plexus has occurred. The transversalis coli and the suprascapular arteries should not be harmed as they are necessary for the anastomotic circulation. If the sternomastoid extends far back upon the clavicle it should have its posterior fibres cut (Fig. 270).

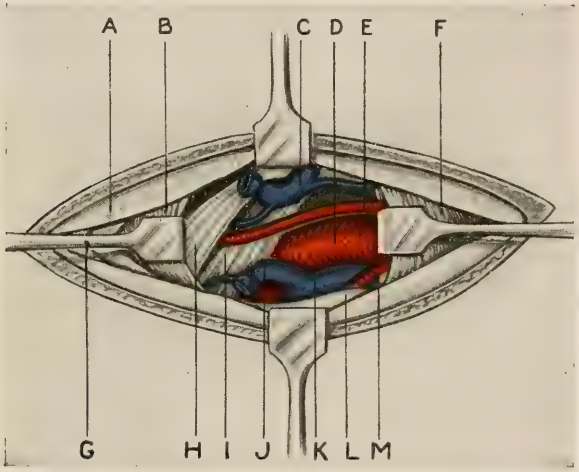


FIG. 270.—THIRD PART OF RIGHT SUBCLAVIAN ARTERY EXPOSED ABOVE CLAVICLE.

A, Fascia overlying platysma; *B*, trapezius; *C*, *J*, external jugular vein; *D*, third part of subclavian artery; *E*, transversalis colli artery; *F*, sternomastoid; *G*, retractor drawing trapezius outward; *H*, posterior belly of omohyoid; *I*, brachial plexus; *K*, subclavian vein; *L*, clavicle; *M*, suprascapular artery. (*After Bickham.*)

The *first portion* of the subclavian is ligated through the same incision as is required for ligation of the innominate artery. If ligation on the left side near the aorta is contemplated, resection of manubrium will give the best access, as is described for approach to the innominate. As the ligature is passed, the pneumogastric nerve and the thoracic duct should be retracted inward, and the phrenic nerve avoided on the outer side.

The *second portion* is ligated through the same incision as the third portion. The phrenic nerve should be retracted to the inner side. The scalenus anticus must be divided transversely and allowed to retract. The artery lies behind the muscle, and is ligated by passing the needle from before backward.

The *indications* for ligation are certain cases of aneurism of the axillary artery, innominate, subclavian or aorta; for wounds; to secure hemostasis in operations for removal of the upper extremity.

Axillary Artery (Figs. 271 and 272).—This vessel is a continuation of the subclavian artery. It begins at the lower and outer border of the first rib and becomes the brachial artery at the lower border of the tendons of the latissimus dorsi and teres major muscles.

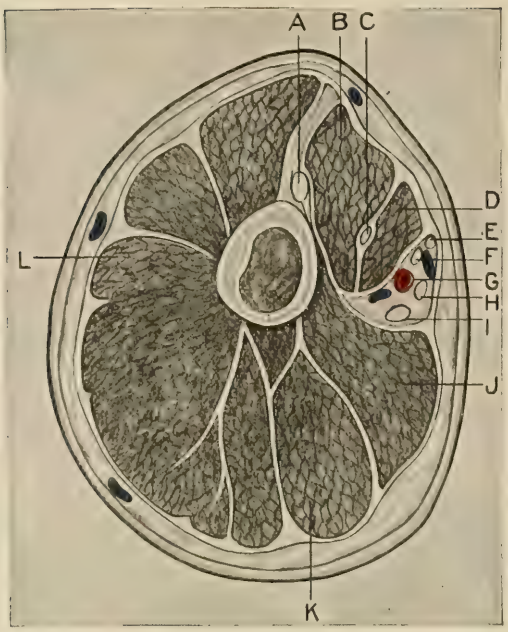


FIG. 271.—CROSS-SECTION OF RIGHT ARM AT AXILLA.

A, Tendon of long head of biceps; *B*, short head of biceps; *C*, musculocutaneous nerve; *D*, coracobrachialis muscle; *E*, internal cutaneous nerve; *F*, median nerve; *G*, axillary artery and veins; *H*, ulnar nerve; *I*, musculospiral nerve; *J*, latissimus dorsi; *K*, triceps; *L*, deltoid.

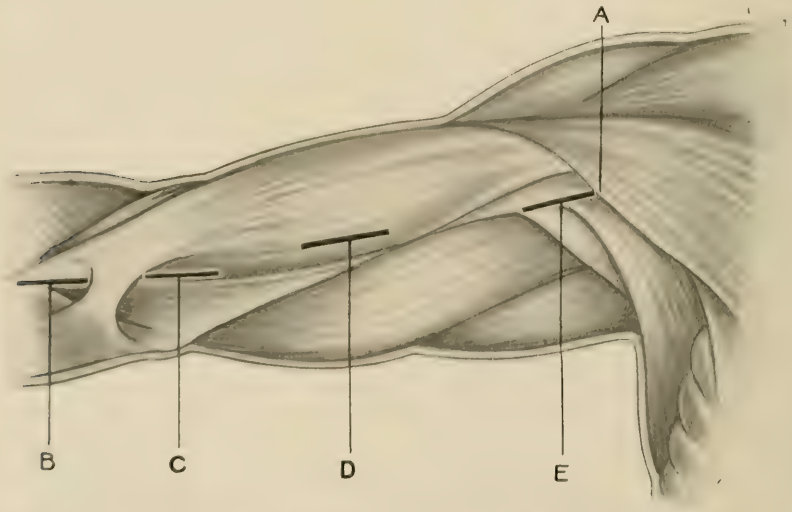


FIG. 272.—INCISIONS FOR EXPOSING AXILLARY AND BRACHIAL ARTERIES.

A, Lower edge of pectoralis major; *B*, incision for exposing artery below bicipital fascia; *C*, for exposing artery at bend of elbow (the last two incisions may be united by dividing bicipital fascia); *D*, for brachial in middle of arm; *E*, for third part of axillary artery. (*After Bickham.*)

The axillary artery is divided into 3 parts for convenience of description. The first is above the pectoralis major, the second is behind, and the third portion is below that muscle. In front of the *first portion* is the subclavius muscle and the cephalic vein; behind is the chest wall; on the outer side is the brachial plexus; and on the inner side is the axillary vein. The *second portion* has behind it the subscapularis muscle and the

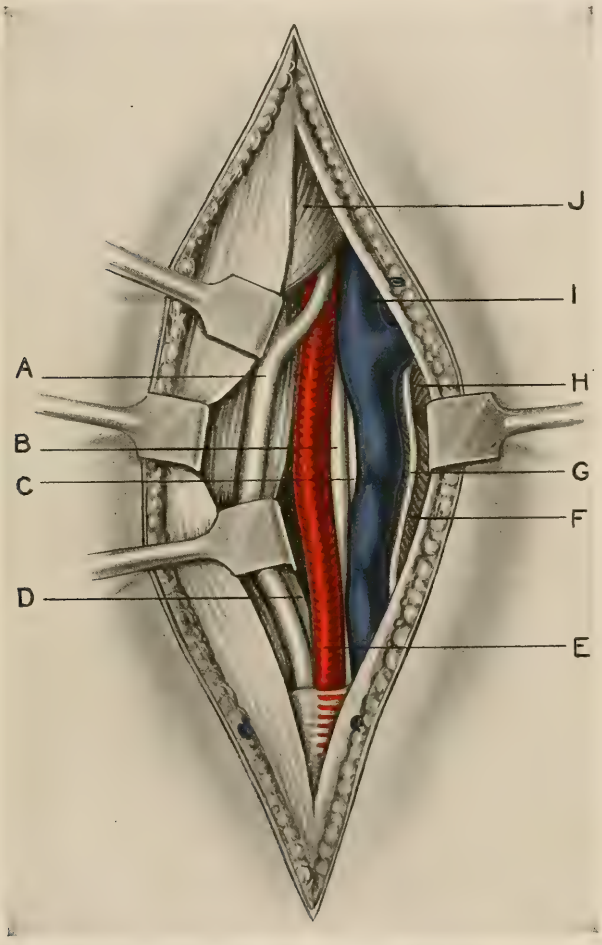


FIG. 273.—THIRD PORTION OF RIGHT AXILLARY ARTERY.

A, Median nerve; *B*, ulnar nerve; *C*, right brachial vena comes; *D*, Coracobrachialis muscle; *E*, axillary artery denuded of sheath; *F*, triceps; *G*, internal cutaneous nerve; *H*, teres major; *I*, basilic vein, which becomes the axillary vein after receiving two brachial venæ comes; *J*, pectoralis major muscle. (*After Bickham.*)

posterior cord of the brachial plexus; on the outer side is the outer cord of the plexus; and on the inner side are the inner cord and the axillary vein. Ligation of the second portion would be difficult. The *third portion* has in front in its upper half the pectoralis major; behind are the subscapularis muscle, the tendons of the latissimus dorsi and teres major, and the musculospiral and circumflex nerves; on the outer side are the coraco-brachialis, median, and musculocutaneous nerves; and on the inner side are the axillary vein, the ulnar and internal cutaneous nerves.

The *third portion* is most accessible. For its ligation the patient lies with the arm abducted to a right angle. The surgeon *sits* with his back toward the patient's feet. An incision is begun in the axilla opposite the head of the humerus and is carried for 8 cm. (3 inches) downward parallel to the lower edge of the pectoralis major in a line with the artery. The fascia is opened and the artery discovered. The vein or veins should be drawn to the inner side. They may be found overlying the artery. The ulnar and internal cutaneous nerves are retracted with the vein. The median nerve should be retracted outward with the external cutaneous. Venæ comites should be separated. The needle should be carried around the artery from within outward well below the circumflex branches (Fig. 273).

The *first portion* is ligated with the patient supine, having a sand bag under the spine to permit the shoulder to drop back. The arm is laid at the side. An incision with a downward convexity is begun at the tip of the coracoid process and carried for 10 cm. (4 inches) along the lower border of the clavicle. It is carried through the deep fascia. The cephalic vein and the acromiothoracic artery appear in the outer part of the wound and should be avoided. The fibers of the pectoralis major should be separated or divided until its posterior fascia appears. This should be penetrated by blunt dissection. The pectoralis minor is to be drawn down. Blunt dissection in the connective tissue discloses the axillary vein. The artery lies on the outer side and behind it. The vein is drawn inward and the ligature passed. There is danger of tearing the vein because of its close attachment to the costocoracoid fascia. The ligature should be applied as near the clavicle as possible. The operation is not an easy one and is rarely called for.

The *indications* for ligation are wounds of the artery, subclavian aneurism, brachial aneurism, excision of cancer involving the vessel, and for rupture of the vessel caused by attempts at reduction of old dislocation of the humerus.

Brachial Artery (Fig. 274).—This vessel runs from the axilla to the front of the elbow lying in the groove between the biceps and triceps on the front and inner aspect of the arm, and covered by the aponeurosis enveloping the biceps muscle. It has two venæ comites. The median nerve lies in front of it, occupying the same sheath and crossing from without inward. The basilic vein lies in front of it between the skin and deep fascia. The ulnar nerve along with an artery and two veins lies in the substance of the triceps behind it. The internal cutaneous nerve lies just to the inner side of the basilic vein.

To ligate at the *lower part*, the arm is abducted and laid upon a table with the forearm supinated. An incision 5 cm. (2 inches) long is made along the inner side of the tendon of the biceps muscle. The median basilic vein is retracted downward and inward. The bicipital fascia is incised, the artery exposed, cleared of its satellite veins, the median nerve retracted inward, and the ligature passed (Fig. 275).

To ligate in the *middle of the arm*, the limb is placed in the same position. An incision 8 cm. (3 inches) long is made along the inner border of the biceps, care being taken not to injure the basilic vein or internal cutaneous nerve. Both of these should be kept posterior to the incision. The aponeurosis reflected from the biceps should be divided and the vessel exposed by retracting the muscle outward. It is found in its sheath with the nerve and veins. These are separated and the artery ligated (Fig. 276).

The *indications* for ligation are wounds of the vessel, wounds of the palmar arch with infection and secondary hemorrhage, and aneurism.

FIG. 274.—CROSS-SECTION OF MIDDLE OF RIGHT ARM.

A, Biceps muscle; *B*, nutrient vessels; *C*, brachialis anticus; *D*, musculospiral nerve and superior profunda artery; *E*, triceps; *F*, brachial artery and veins, inferior profunda artery, and median and ulnar nerves.

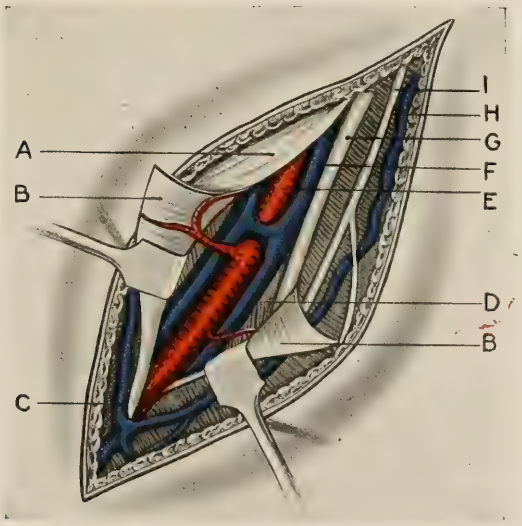


FIG. 275.—RIGHT BRACHIAL ARTERY AT ELBOW.

A, Biceps muscle; *B*, *B*, bicipital fascia divided and retracted; *C*, median cephalic vein; D, brachialis anticus muscle; *E*, brachial artery; *F*, brachial venæ comites; *G*, median nerve; *H*, median basilic vein; *I*, internal cutaneous nerve. (*After Bickham.*)

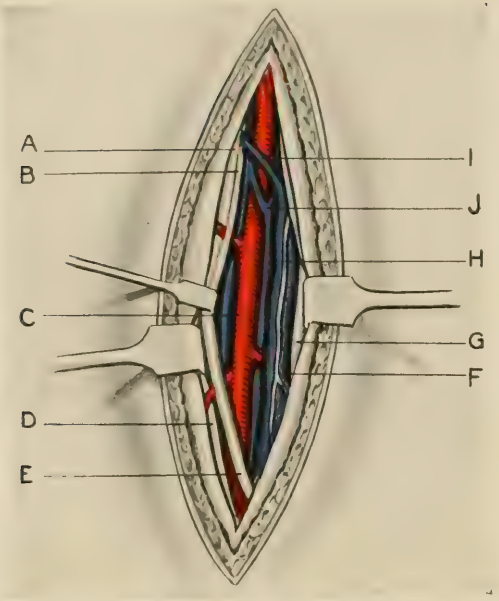


FIG. 276.—RIGHT BRACHIAL ARTERY AT MIDDLE OF ARM.

A, Coracobrachialis muscle retracted outward; *B*, *E*, median nerve; *C*, brachial artery; *D*, biceps; *F*, basilic vein; *G*, ulnar nerve; *H*, internal cutaneous nerve; *I*, branch between basilic and cephalic veins; *J*, venæ comites. (*After Bickham.*)

FIG. 277.—CROSS-SECTION OF RIGHT FOREARM JUST BELOW ELBOW JOINT.

A, Supinator longus; *B*, radial recurrent artery, radial and interosseous nerves; *C*, extensor carpi radialis longior; *D*, extensor carpi radialis brevior; *E*, extensor carpi ulnaris; *F*, anconeus; *G*, postacromial bursa; *H*, flexor carpi ulnaris; *I*, ulnar nerve and posterior ulnar recurrent artery; *J*, flexor sublimis digitorum; *K*, median nerve and anterior ulnar recurrent artery; *L*, tendon of biceps; *M*, bifurcation of brachial artery into radial and ulnar; *N*, pronator radii teres; *O*, median basilic vein.

Radial Artery (Figs. 277 and 278).—The radial artery lies in a line drawn from a point 1.25 cm. (½ inch) below the center of the bend of the elbow to the ulnar side of the styloid process of the radius. It lies in the groove made by the supinator longus on the outer side and the pronator radii teres and the flexor carpi radialis on the ulnar side. It is covered by the skin, cellular tissue and aponeurosis. It has two venæ comites. No nerve accompanies it. The radial nerve lies in the sheath of the supinator longus but passes behind and to the outer side and should not be exposed in the operation.

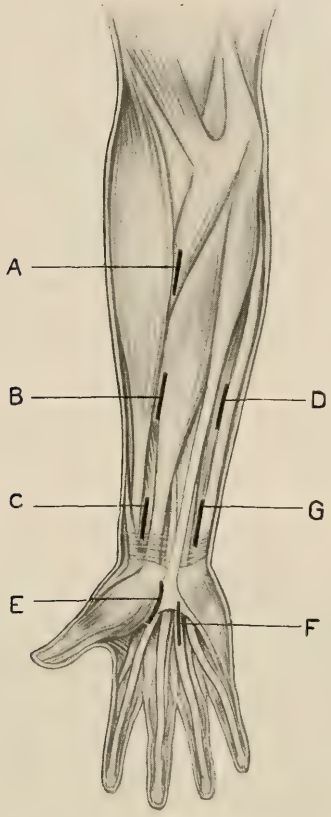


FIG. 278.—INCISIONS FOR EXPOSING RADIAL AND ULNAR ARTERIES AND PALMAR ARCHES.
A, For ligation of radial artery in upper third of forearm; *B*, for radial in middle third; *C*, for radial in lower third; *D*, for ulnar in middle third; *E*, for deep palmar arch; *F*, for superficial palmar arch.

To ligate in the *upper third*, an incision 6 cm. (2½ inches) long is made in the line of the artery beginning 4 cm. (1½ inches) below the fold of the elbow. The superficial veins should be avoided. The aponeurosis of the supinator longus is divided along the ulnar side of the muscle. This exposes the fibers of the pronator radii teres. The two muscles are retracted apart exposing the artery. The veins should be separated from it and the ligature applied (Figs. 279 and 280).

To ligate in the *lower third*, an incision 5 cm. (2 inches) long is made in the line of the vessel ending 2.5 cm. (1 inch) above the wrist. Here the

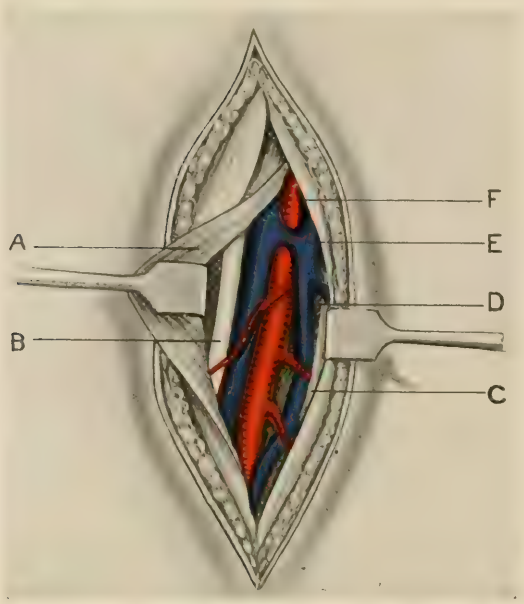


FIG. 279.—RIGHT RADIAL ARTERY EXPOSED IN UPPER PART OF FOREARM.

A, Supinator longus; *B*, radial nerve; *C*, flexor carpi radialis; *D*, pronator radii teres behind vein; *E*, radial venæ comites; *F*, radial artery. (*After Bickham.*)

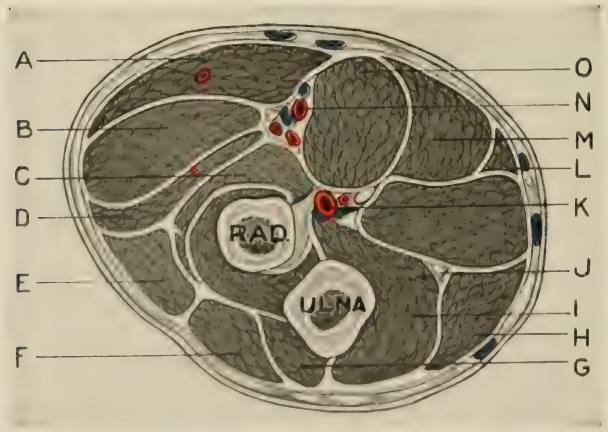


FIG. 280.—CROSS-SECTION OF UPPER THIRD OF RIGHT FOREARM.

A, Supinator longus; *B*, extensor carpi radialis longior; *C*, supinator brevis; *D*, extensor carpi radialis brevior; *E*, extensor communis digitorum; *F*, extensor carpi ulnaris; *G*, anconeus; *H*, flexor carpi ulnaris; *I*, flexor profundus digitorum; *J*, ulnar nerve; *K*, ulnar and interosseous arteries and veins and median nerve; *L*, subcutaneous vein and nerve; *M*, flexor carpi radialis; *N*, radial artery, descending branches, veins, and nerve; *O*, pronator radii teres.

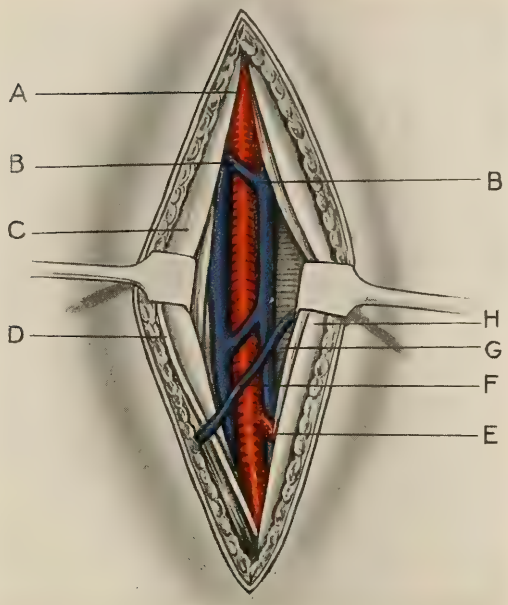


FIG. 281.—RIGHT RADIAL ARTERY EXPOSED IN LOWER THIRD JUST ABOVE THE WRIST.

A, Radial artery; *B*, *B*, venæ comites; *C*, supinator longus; *D*, anterior branch of musculo-cutaneous nerve; *E*, superficialis volæ artery; *F*, radial vein; *G*, pronator quadratus; *H*, flexor carpi radialis. (*After Bickham.*)

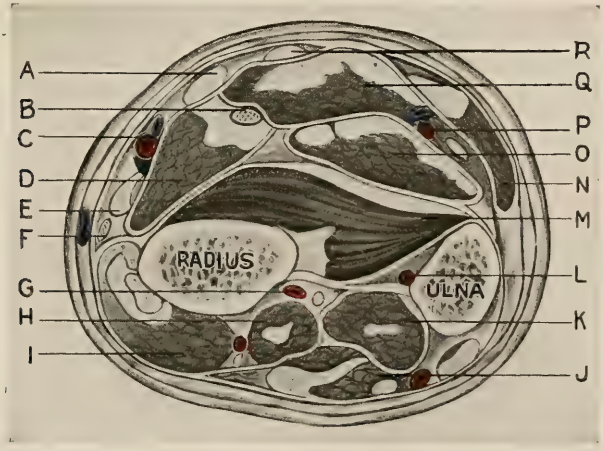


FIG. 282.—CROSS-SECTION OF LOWER THIRD OF RIGHT FOREARM.

A, Flexor carpi radialis; *B*, median nerve; *C*, radial artery and veins; *D*, flexor longus pollicis; *E*, supinator longus; *F*, radial nerve; *G*, posterior interosseous artery and nerve; *H*, extensor longus pollicis; *I*, extensor proprius pollicis; *J*, extensor communis digitorum; *K*, extensor indicis; *L*, anterior interosseous artery; *M*, pronator quadratus; *N*, flexor carpi ulnaris; *O*, flexor profundus digitorum; *P*, ulnar artery, veins, and nerve; *Q*, flexor sublimis digitorum; *R*, palmaris longus.

artery is superficial. It is easily separated from the two veins and ligated (Figs. 281 and 282).

The *indications* for operation are for transfusion, for wounds and aneurism. To control wounds, it is best to expose the bleeding place and ligate there. To control bleeding from the *palmar arch* it is best to cut down and find the bleeding point. But in secondary hemorrhage with infection ligation of the radial and ulnar arteries above the wrist often is called for. Some surgeons prefer ligation of the brachial for this condition.

Ulnar Artery.—The ulnar artery is the larger of the two subdivisions of the brachial. It begins just below the elbow, and passes obliquely downward to the inner side of the forearm, and runs down the ulnar border to

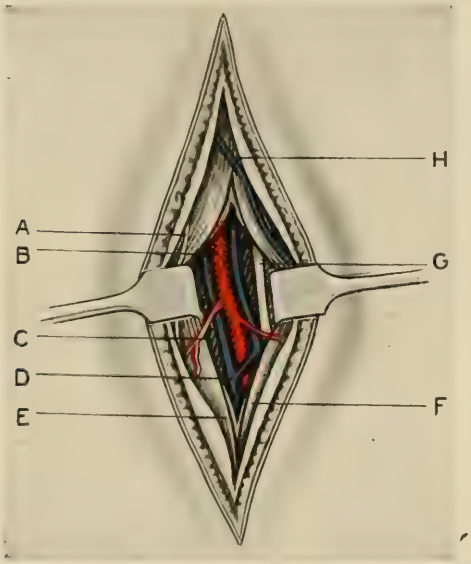


FIG. 283.—ULNAR ARTERY EXPOSED IN UPPER PART OF MIDDLE THIRD OF FOREARM.

A, Anterior branch of internal cutaneous nerve; *B*, ulnar artery; *C*, flexor profundus digitorum; *D*, venæ comites; *E*, flexor sublimis digitorum; *F*, flexor carpi ulnaris; *G*, ulnar nerve; *H*, anterior ulnar vein. (*After Bickham.*)

the wrist. It crosses the annular ligament on the radial side of the pisiform bone and passes across the palm of the hand, forming the superficial palmar arch. In its upper third it lies beneath the superficial layer of muscles. At the inner side of the arm it becomes superficial, lying between the flexor carpi ulnaris on the inside and the flexor sublimis digitorum on the outside. In its lower two-thirds it lies in the direction of a line passing from the internal condyle to the outer border of the pisiform bone. It has two veins. It is joined by the ulnar nerve as it reaches the inner border of the arm. The nerve lies on the inner side. The artery is easily accessible at any point in its lower two-thirds.

To ligate in the *middle* (Fig. 283) of the arm, an incision is made in the line of the artery beginning 8 cm. (3 inches) below the internal condyle and extending downward 9 cm. (3½ inches). The fascia is to be well exposed, and the first intermuscular septum in front of the ulna will be found to be between the flexor carpi ulnaris and the flexor sublimus digitorum. Open

FIG. 284.—CROSS-SECTION OF MIDDLE OF RIGHT FOREARM.

A, Flexor carpi radialis; *B*, median nerve; *C*, supinator longus; *D*, radial artery, veins, and nerve; *E*, flexor longus pollicis; *F*, extensor carpi radialis; *G*, extensor ossis metacarpi pollicis; *H*, extensor communis digitorum; *I*, extensor minimi digiti; *J*, extensor carpi ulnaris; *K*, extensor indicis; *L*, anterior interosseous vessels; *M*, flexor profundus digitorum; *N*, ulnar artery, veins, and nerve; *O*, flexor carpi ulnaris; *P*, flexor sublimis digitorum.

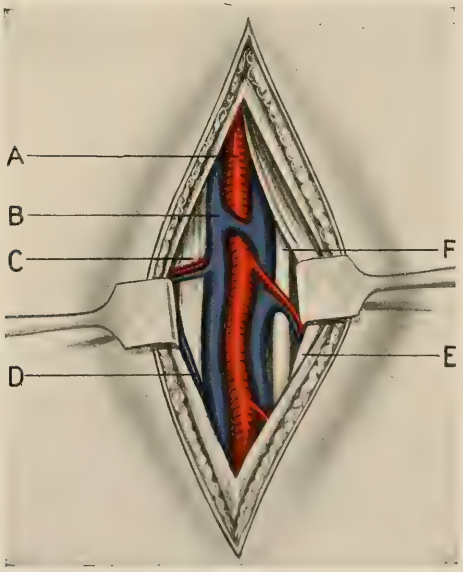


FIG. 285.—ULNAR ARTERY EXPOSED IN LOWER THIRD JUST ABOVE WRIST.

A, Ulnar artery; *B*, ulnar venæ comites; *C*, flexor sublimis digitorum; *D*, anterior ulnar vein; *E*, flexor carpi ulnaris; *F*, ulnar nerve. (*After Bickham.*)

this space and retract the flexor carpi ulnaris inward and the flexor sublimus digitorum outward. First the nerve will come into view and then the artery. Separate the veins and ligate (Fig. 284).

To ligate in the *lower third*, an incision should be made to the radial side of the tendon of the flexor carpi ulnaris. This should be about 5 cm. (2 inches) long and should end 2.5 cm. (1 inch) above the end of the ulna. The fascia should be divided and the artery easily discovered and ligated. The nerve must be avoided (Fig. 285).

The *indications* for ligation are the same as for ligation of the radial artery.

Deep Palmar Branch of the Radial Artery.—This is the continuation of the radial artery and forms the deep palmar arch. It extends from the upper end of the first interosseous space to the base of the fifth metacarpal bone. The incision should curve about the base of the thenar eminence in the palm and end below opposite the head of the second metacarpal. The *superficial palmar arch* is ligated. It crosses the palm at the level of the lower border of the abducted and extended thumb. The muscles of the thenar eminence and the annular ligament are exposed and divided to as limited an extent as possible. The dissection is then carried back between the tendons and muscles of the index finger on one side and the muscles of the thumb on the other side. The branches of the median nerve must be protected. The abductor obliquus pollicis, which is exposed in the interval, should be divided vertically. The arch then comes into view as it passes transversely from between the adductor obliquus and the adductor transversus pollicis into the deep fascia lying on the interossei. It is about 2 cm. (¾ inch) nearer the wrist than the superficial arch (Fig. 286).

Abdominal Aorta.—The abdominal aorta is ligated for aneurism of the aorta or common iliac, injury and pathologic rupture. The place of election is below the inferior mesenteric (see Aneurism of Abdominal Aorta, page 397). The abdomen is opened by a median incision (see Abdomen). The bifurcation is on the left side of the fourth lumbar vertebra, 1.25 cm. (½ inch) below the umbilicus. This is on a line connecting the highest points of the two iliac crests. The intestines should be held aside and the posterior layer of the peritoneum exposed. The patient should be in the Trendelenburg position. The peritoneum is incised over the artery, and the retroperitoneal space entered. The nerves of the aortic plexus are retracted by blunt dissection. Lying on the right side of the vessel are the inferior vena cava, the vena azygos, the thoracic duct and the right semilunar ganglion. These structures are avoided and the needle is passed from right to left behind the vessel. A needle longer than the ordinary aneurism needle is required or one from which the curved section can be unscrewed. The principles of ligation are discussed under Aneurism.

Common Iliac Artery.—The common iliac artery begins at the bifurcation of the aorta opposite the left side of the lower border of the fourth lumbar vertebra. This is opposite a point 1.25 cm. (½ inch) below and 1.25 cm. (½ inch) to the left of the umbilicus. A line drawn from this point to the middle of a line between the anterior superior spine of the ilium and the symphysis of the pubes represents the course of the common and external iliac arteries; the upper third of this line representing the first and the lower two-thirds representing the latter. In front of the common arteries are the peritoneum, sympathetic nerves, ureter (just above the bifurcation), and on the left side the superior hemorrhoidal artery. Behind are the common iliac veins. The vein lies also on the outer side of the right common iliac

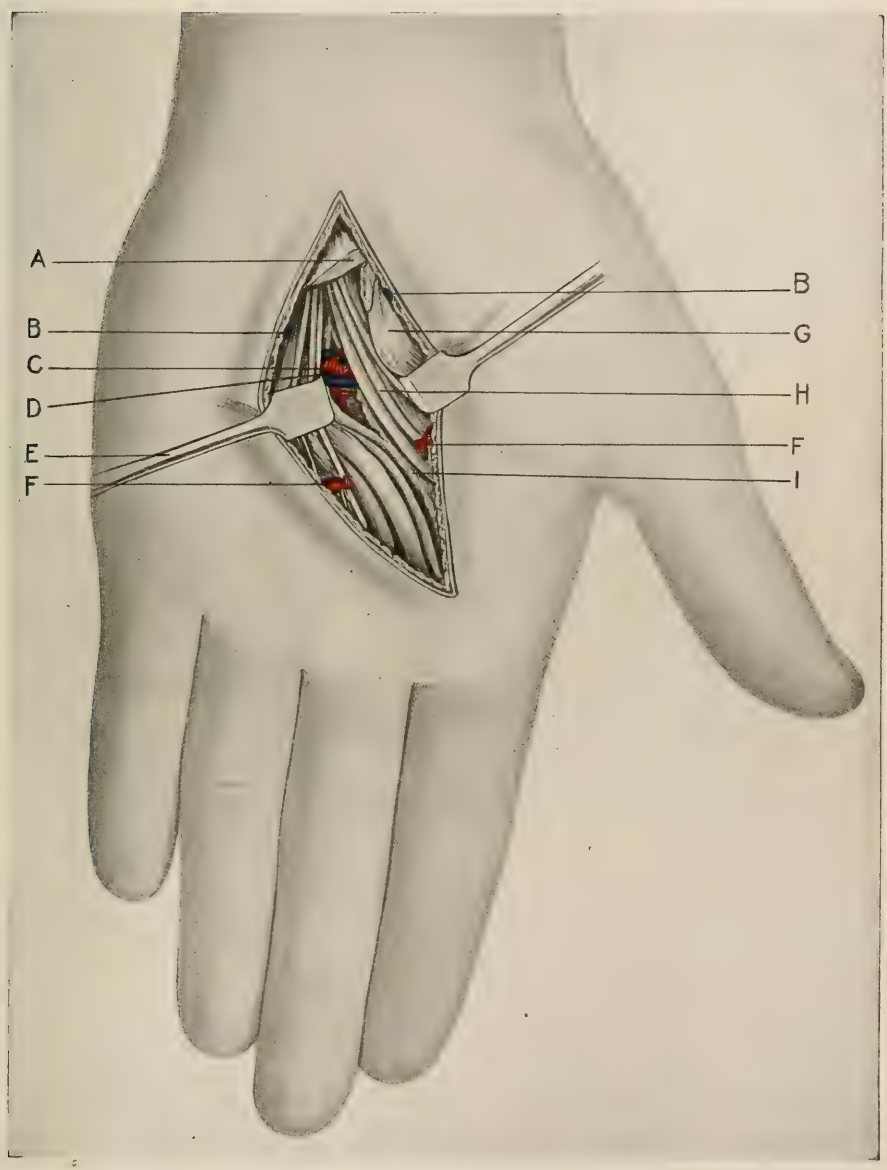


FIG. 286.—SUPERFICIAL AND DEEP PALMAR ARCHES EXPOSED IN LEFT HAND.

A, Annular ligament; *B*, superficial palmar vein; *C*, deep palmar arch and veins; *D*, *H*, branches of median nerve; *E*, retractor drawing deep fascia inward; *F*, *F*, superficial palmar arch; *G*, flexor brevis pollicis; *I*, deep palmar fascia.

artery, and on the inner side of the left common iliac. The psoas muscle is on the outer side (Fig. 287).

The vessel is best ligated *through the abdomen.* The patient is placed in the lowered-head position. The abdomen is opened below the umbilicus. The intestines are pressed upward and held. The artery is easily identified. The peritoneum is picked up and divided. The ureter should be identified. The artery is cleared of areolar tissue, the ureter drawn aside and the needle passed away from the vein. The peritoneal wound falls together without a suture.

Extraperitoneal ligation is done in the following manner: An incision is made 2 cm. (¾ inch) above Poupart's ligament, beginning below just out-

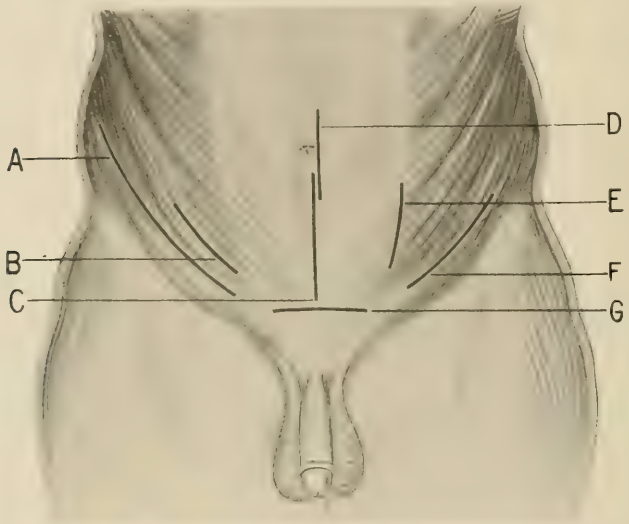


FIG. 287.—INCISIONS FOR EXPOSING ABDOMINAL AND PELVIC VESSELS.

A, Incision for exposure of abdominal aorta, common iliac, and internal iliac by the retroperitoneal route; *B*, for exposure of external iliac through the peritoneum; *C*, for exposure of common, external, and internal iliac arteries through the peritoneum; *D*, for exposure of abdominal aorta through the peritoneum; *E*, for exposure of common, internal and external iliac arteries through the peritoneum; *F*, for exposure of external and deep epigastric arteries behind peritoneum; *G*, suprapubic retroperitoneal exposure of bladder and related vessels.

side of the external iliac and curved upward internal to the anterior superior spine of the ilium. It should be from 10 to 15 cm. (4 to 6 inches) long. Everything is divided down to the aponeurosis of the external oblique muscle, which should be cleared and split open through the whole length of the wound. The fibres of the internal oblique and transversalis should then be separated or divided by careful dissection and retracted inward. The transversalis fascia will then come into view. The fascia should be picked up in the lower end of the wound and incised. The fascial side of the peritoneum is thus exposed. The fascia is then divided throughout the length of the wound and the peritoneum pressed away. The peritoneum is next stripped up from the psoas and iliacus muscles. The external iliac artery is felt and followed up to the common iliac. The peritoneum is lifted up with the finger. The ureter is found adherent to the peritoneum, and should be separated with it from the vessel. Not a good view of the artery can be

obtained, and the needle must be passed from within outward by feeling. The transperitoneal operation is preferable to this (Fig. 288).

The *indications* for operation are aneurism of the external iliac and wounds. These rarely call for ligation.

External Iliac Artery.—The course of this vessel has been described with the common iliac. It ends at Poupart's ligament under which it passes and becomes the femoral artery. It is covered in front by peritoneum and intestines. Near Poupart's ligament it is crossed by the spermatic vessels, the genital branch of the genitocrural nerve, the circumflex iliac vein and

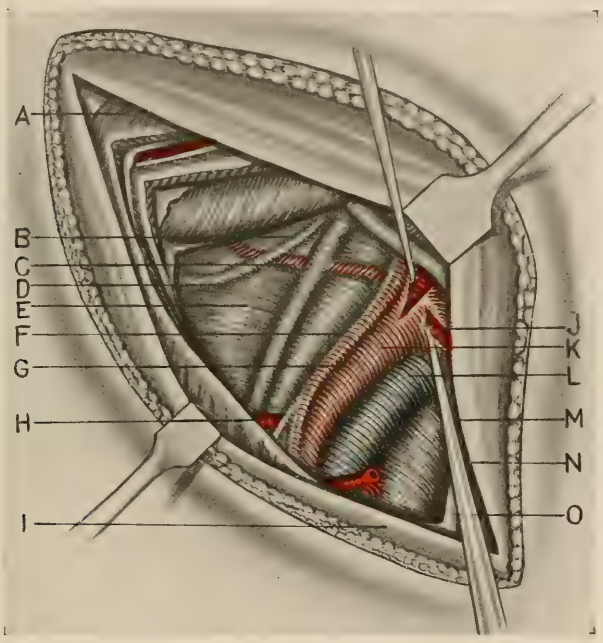


FIG. 288.—RIGHT COMMON AND INTERNAL ILIAC ARTERIES EXPOSED BY EXTRAPERITONEAL INCISION.

A, Internal oblique muscle; *B*, external cutaneous nerve; *C*, iliolumbar artery; *D*, anterior crural nerve; *E*, iliac fascia; *F*, genitocrural nerve; *G*, spermatic artery; *H*, deep circumflex artery; *I*, external oblique muscle and aponeurosis; *J*, internal iliac artery exposed by incision in sheath; *K*, external iliac artery; *L*, external and internal iliac veins; *M*, *N*, retracted peritoneum covered by external oblique; *O*, conjoined tendon. (*After Bickham.*)

lymphatic vessels and glands. Behind is the external iliac vein. On the inner side are the external iliac vein and the vas deferens at the femoral arch. The psoas magnus muscle lies externally and behind.

To ligate the artery an incision is begun at the outer side of the vessel 1.25 cm. (½ inch) *above Poupart's ligament* and carried upward and outward parallel to the ligament and then curved upward. It should be 8 or 10 cm. (3 or 4 inches) long. This is carried through the abdominal wall and the peritoneum is raised from the psoas and iliacus muscles just as for ligation of the common iliac by the extraperitoneal route. The thighs should then be flexed to relax the muscles, the peritoneum and abdominal wall are retracted upward and inward and the artery discovered lying along the inner border of the psoas muscle. It is then isolated and the needle is passed from within outward. The anterior crural nerve lies on the outer

side of the artery. This operation is made high enough not to open the inguinal canal. The ligature is applied about the middle of the artery (Fig. 289).

This vessel may be more easily reached *through the abdomen* by an incision through the rectus muscle. The patient is placed in the lowered-head position, and the intestines retracted upward. The peritoneum over the vessel is incised and the vessel easily surrounded by a ligature. Care to avoid the vein and ureter are necessary. This operation is in nearly all cases preferable to the extraperitoneal operation.

The *indications* for operation are for high femoral aneurism and for wounds which can not be sutured.

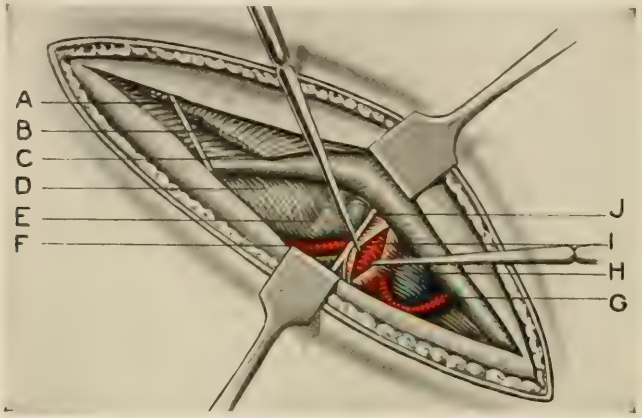


FIG. 289.—RIGHT EXTERNAL ILIAC ARTERY EXPOSED BY EXTRAPERITONEAL INCISION.

A, Ilio-inguinal nerve; *B*, transversalis muscle; *C*, peritoneum, stripped back and retracted; *D*, iliac fascia; *E*, location of anterior crural nerve beneath fascia; *F*, deep circumflex iliac artery; *G*, deep epigastric artery; *H*, fascia covering external iliac vein; *I*, external iliac artery; *J*, genitocrural nerve. (*After Bickham.*)

Internal Iliac Artery.—This vessel begins at the bifurcation of the common iliac opposite the sacroiliac joint and passes directly down into the pelvic canal. The ureters, having crossed the vessels just above or at the bifurcation of the common iliac, dip down into the pelvis posterior to the internal iliacs, although they may sometimes cross them or lie in front. The veins lie behind. The psoas muscle is to the outer side.

The ligation of the vessel is best accomplished through the abdomen. Extraperitoneal ligation is practicable but difficult and hazardous. Both operations are performed with the same steps as are used for ligation of the common iliac.

The *indications* for the operation are aneurism of the gluteal region, uncontrollable bleeding from terminal branches, operations for tumors of the uterus, and for resection of the rectum.

Gluteal Artery.—This vessel, which is a continuation of the posterior division of the internal iliac, emerges from the pelvis through the greater sacrosciatic foramen above the pyriformis muscle. It is covered by the gluteus maximus muscle. The superior gluteal nerve lies below the artery. The vessel and nerve are exposed as follows: The patient lies prone or on his side. A free incision should be made in the line between the posterior superior spine of the ilium to the top of the great trochanter. The vessel

lies at the middle third of this line. The incision should divide the gluteus maximus muscle and the underlying fascia. The gluteus medius should be retracted upward. The sacrosciatic foramen can then be felt. The vessel emerges from it just above the pyriformis muscle (Fig. 290).

Sciatic Artery.—This is the larger of the terminal branches of the anterior division of the internal iliac artery. It leaves the pelvis through the great sacrosciatic foramen between the pyriformis and the coccygeus muscles, and passes down between the tuberosity of the ischium and the great trochanter. It lies just internal to the great sacrosciatic nerve. The small sciatic nerve is external and posterior to the vessel. It is covered by the gluteus maximus muscle. The vessel emerges from the great sacrosciatic foramen opposite

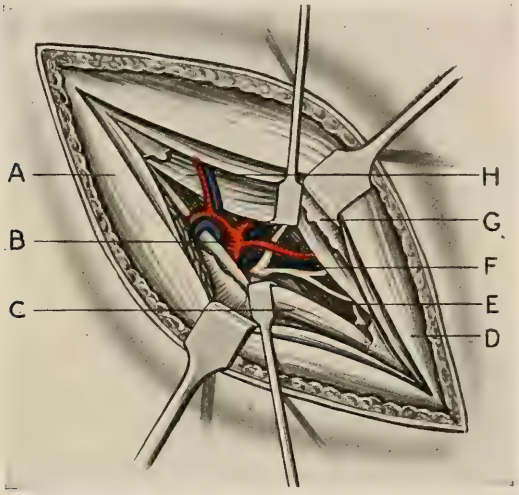


FIG. 290.—RIGHT GLUTEAL ARTERY EXPOSED THROUGH BUTTOCK ABOVE THE PYRIFORMIS.

A, Fascia lata covering gluteus maximus; *B*, gluteal artery and veins; *C*, pyriformis, retracted downward; *D*, fascia lata covering gluteus maximus; *E*, gluteus minimus; *F*, superior gluteal nerve; *G*, divided deep fascia between gluteus maximus and gluteus medius and pyriformis; *H*, gluteus medius. (*After Bickham.*)

a point at the junction of the upper and middle thirds of a line connecting the posterior superior spine of the ilium and the lower part of the great trochanter. A free incision must be made over the vessel dividing the gluteus maximus muscle. The notch is found, and the artery discovered at the lower border of the pyriformis muscle (Fig. 291).

Internal Pudic Artery.—This artery, one of the termini of the internal iliac in the pelvis, passes to the lower margin of the great sacrosciatic foramen, and leaves the pelvis between the pyriformis and coccygeus muscles. It then crosses the spine of the ischium and reënters the pelvis through the lesser sacrosciatic foramen. It is ligated through the same incision as is employed for the sciatic artery. The artery is found below the spine of the ischium (Fig. 291).

The ligation of either of these three last described arteries, excepting *in situ* for a wound, is rarely called for; and when it is, the ligation of the internal iliac will be found to be an easier procedure.

Femoral Artery (Fig. 292).—The femoral artery is the continuation of the external iliac under Poupart's ligament, beginning midway between the an-

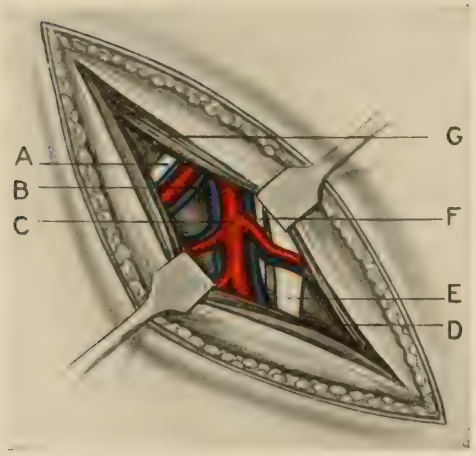


FIG. 291.—RIGHT INTERNAL PUDIC AND SCIATIC ARTERIES EXPOSED THROUGH BUTTOCK BELOW PYRIFORMIS.

A, Internal pudic nerve; *B*, pudic artery and veins; *C*, sciatic artery and veins; *D*, obturator internus; *E*, great sciatic nerve; *F*, small sciatic nerve; *G*, pyriformis, retracted upward. (*After Bickham.*)

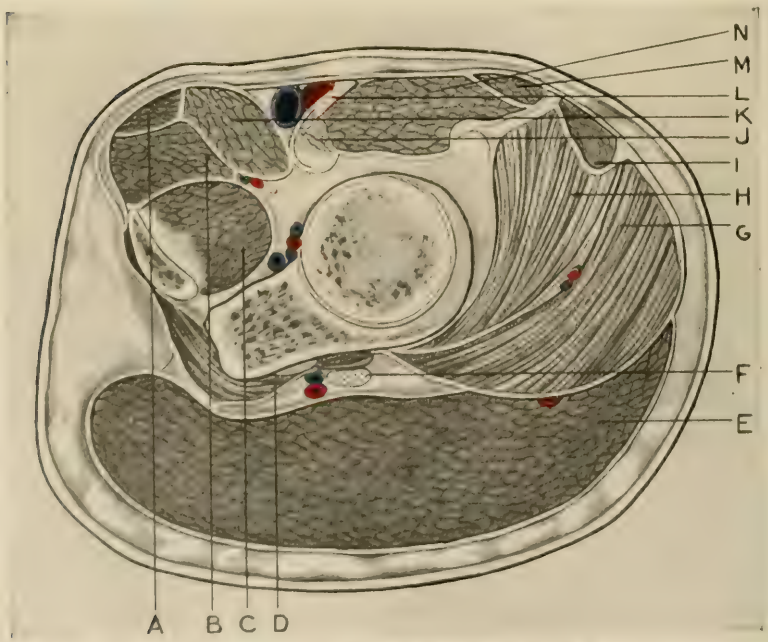


FIG. 292.—CROSS-SECTION OF LEFT THIGH AT LEVEL OF HEAD OF FEMUR.

A, Adductor longus; *B*, adductor brevis; *C*, obturator externus; *D*, obturator internus; *E*, gluteus maximus; *F*, great sciatic nerve, artery and vein; *G*, gluteus medius; *H*, gluteus minimus; *I*, tensor vaginæ femoris; *J*, psoas; *K*, pectineus; *L*, femoral artery and vein and crural nerve; *M*, sartorius; *N*, iliacus.

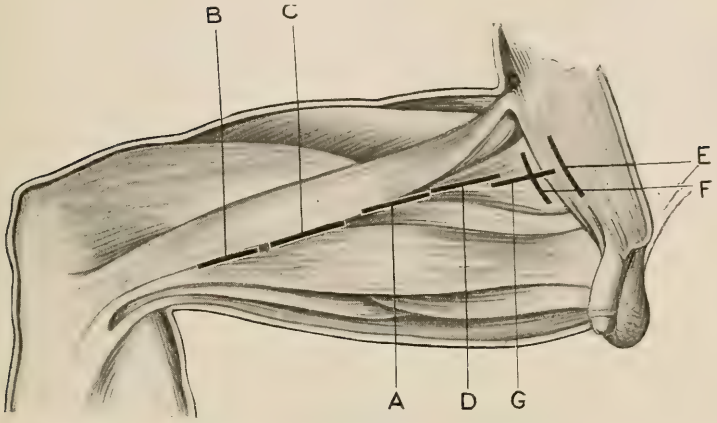


FIG. 293.—INCISIONS FOR EXPOSURE OF FEMORAL ARTERY.

A, Incision for exposure of femoral artery at lower part of Scarpa's triangle; *B*, for popliteal at upper part of popliteal space from inner side of thigh; *C*, for femoral in Hunter's canal; *D*, for profunda femoris at its origin; *E*, for exposure of external iliac; *F*, for femoral just below Poupart's ligament. (*After Bickham.*)

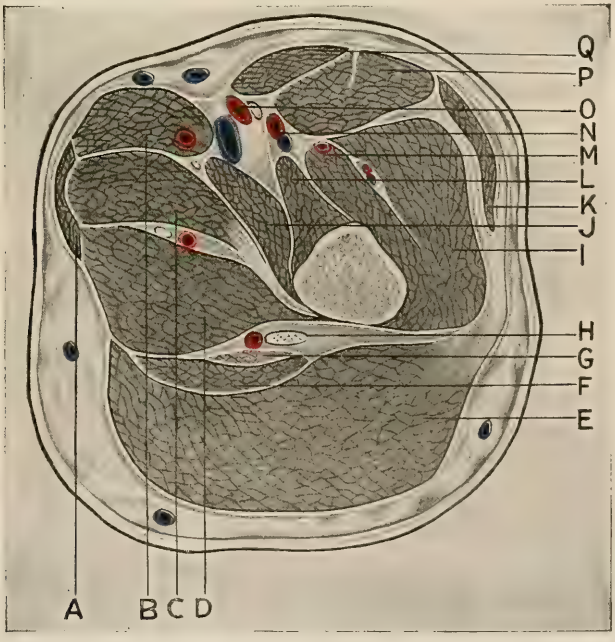


FIG. 294.—CROSS-SECTION OF LEFT THIGH AT LEVEL OF LESSER TROCHANTER.

A, Gracilis; *B*, adductor longus; *C*, adductor brevis; *D*, adductor magnus; *E*, gluteus maximus; *F*, biceps and semitendinosus; *G*, sememembranosus; *H*, sciatic nerve and artery; *I*, vastus externus; *J*, pectineus; *K*, tensor vaginæ femoris; *L*, iliacus; *M*, crureus; *N*, profunda femoris artery and vein; *O*, femoral artery, vein, and anterior crural nerve; *P*, rectus femoris; *Q*, sartorius.

terior-superior spine of the ilium and the pubic symphysis. From in front it passes to the inner side of the thigh, thence toward the back of the thigh, and terminates at the opening in the adductor magnus muscle at the junction of the middle and lower thirds of the thigh where it becomes the popliteal (Fig. 293).

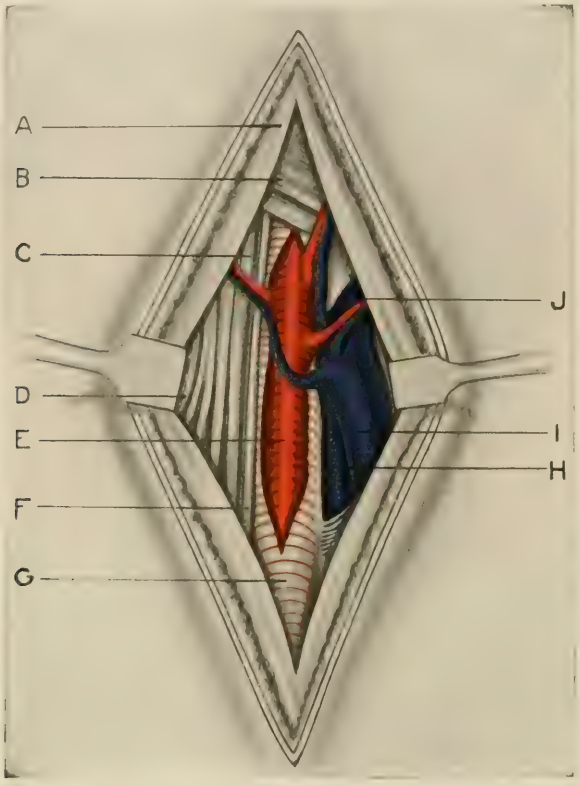


FIG. 295.—RIGHT FEMORAL ARTERY EXPOSED BELOW POUPART'S LIGAMENT.
A, Superficial layer of deep fascia; *B*, external oblique muscle and Poupart's ligament; *C*, anterior crural nerve; *D*, psoas; *E*, femoral artery, showing superficial epigastric, external pudic, and circumflex iliac branches; *F*, crural branch of genitocrural nerve; *G*, fascia lata covering artery; *H*, femoral vein; *I*, internal saphenous vein, showing superficial epigastric, external pudic, and circumflex iliac veins; *J*, femoral vein. (*After Bickham.*)

The femoral artery follows the direction of a line drawn from the point of its beginning to the abductor tubercle on the inner side of the inner condyle of the femur, the thigh being abducted and rotated outward. It is separated from the bone throughout its course by the muscles. In its upper part, for its first 13 cm. (5 inches), in Scarpa's triangle, it is superficial, being covered by the skin, superficial and deep fascias; behind are the muscles; internally is the femoral vein, receiving the long saphenous through the saphenous opening in the fascia lata about 1½ inches below Poupart's ligament; and externally about 1.25 cm. (½ inch) away is the anterior crural nerve. The profunda femoris comes from the outer side about 5 cm. (2 inches) below Poupart's ligament and plunges deeply into the muscles behind. The femoral artery is enclosed in a common sheath with the vein, there being a septum between. The long saphenous nerve from the anterior crural is on the outer side of the artery throughout its course. At the lower angle of Scarpa's triangle the vessel passes beneath the sartorius muscle and enters Hunter's canal. Here the vein becomes posterior and then external to the artery. The vein is always on the opposite side of the artery from the sartorius muscle. Above the profundis femoris, the artery gives off the superficial external pudic, superficial epigastric and superficial circumflex iliac branches (Fig. 294).

Ligation *below Poupart's ligament* is done through a 5-cm. (2-inch) incision, having its centre over the lower border of the ligament. The deep fascia is opened just below the ligament, and the artery exposed. The needle is passed from within outward, avoiding the vein and the crural branch of the genitocrural nerve (Fig. 295).

Ligation at the *lower part of Scarpa's triangle* is the operation of choice. An incision 8 or 10 cm. (3 or 4 inches) long is made, the centre of which shall be a little above the point where the inner border of the sartorius crosses the line of the artery. This crossing represents the apex of the triangle which is about 13 cm. (5 inches) from the centre of Poupart's ligament. The point of election may also be found in a full-sized man, with the thigh abducted and rotated

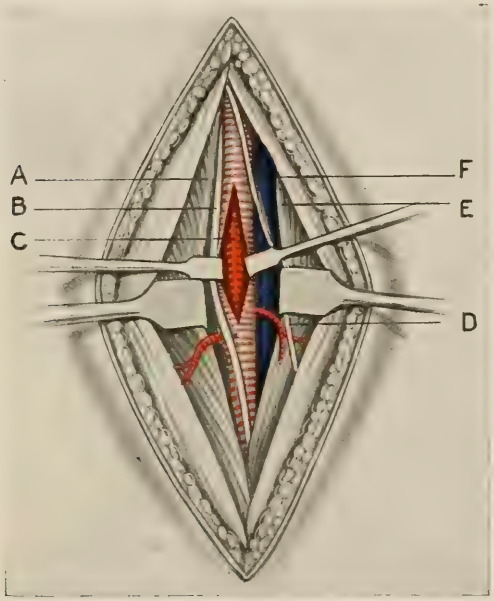


FIG. 296.—RIGHT FEMORAL ARTERY EXPOSED IN LOWER PART OF SCARPA'S TRIANGLE.

A, Sartorius; *B*, long saphenous nerve; *C*, femoral artery exposed through incision in its sheath; *D*, internal cutaneous nerve; *E*, adductor longus; *F*, femoral vein. (*After Bickham.*)

outward, 18 cm. (7 inches) from the anterior-superior spine of the ilium on a line marking the shortest distance between the spine and the middle of the popliteal space. The internal saphenous wire should be to the inner side of the wound. The fascia lata should be divided exposing the fibres of the sartorius muscle which are the only muscular fibers directed downward and inward. By retracting the muscle outward the sheath of the vessel is discovered. The cutaneous branches of the anterior crural nerve should be drawn aside. The sheath is opened and the vessel tied, care being taken to avoid the vein on the inner side and the nerve on the outer side (Fig. 296).

Ligation in the *middle of the thigh* is accomplished through the same incision. The sartorius is retracted outward farther down; the thigh is slightly flexed and rotated outward; and the vessel tied as above. Here the vein lies behind the artery (Fig. 297).

Ligation in *Hunter's canal* is the most difficult of the three operations. With the patient lying on his back, the thigh should be abducted, the leg flexed, the thigh rotated outward, and the heel carried as near to the perineum as possible. The knee is pressed back toward the table. This makes the adductor longus strongly tense, forming a ridge.

The outer side of the knee should rest on a sand bag. The tendon of insertion of the adductor magnus is felt to be tense. The incision 9 cm. (3 or 4 inches) long is made, the centre of the incision being at the junction of the middle and lower thirds of the thigh. The incision is made 1.25 cm. (½ inch) to the inner side of the line representing the course of the vessel

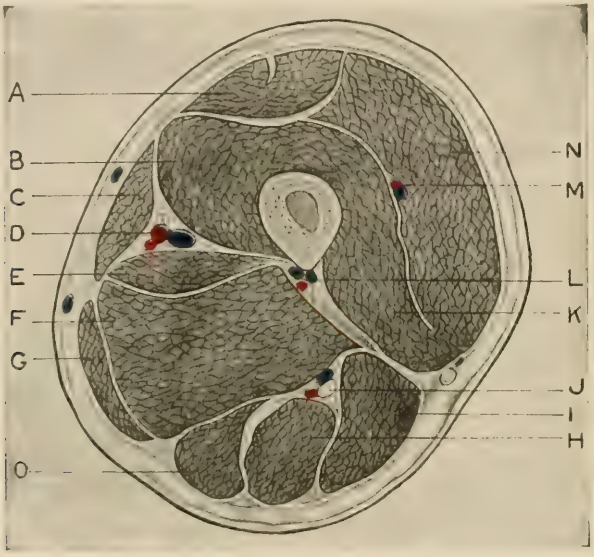


FIG. 297.—CROSS-SECTION AT MIDDLE OF LEFT THIGH.

A, Rectus femoris; *B*, vastus internus; *C*, sartorius; *D*, femoral artery, vein and saphenous nerve; *E*, adductor longus; *F*, adductor magnus; *G*, gracilis; *H*, semitendinosus; *I*, biceps; *J*, great sciatic nerve and vessels; *K*, crureus; L, profunda femoris; *M*, descending branch of external circumflex; *N*, vastus externus; *O*, semimembranosus.

and parallel to it. In dividing the skin and fascia the internal saphenous vein should be avoided. The aponeurosis should be divided, exposing the fibres of the sartorius and of the vastus internus which are at right angles to one another. The sartorius is retracted upward and outward and the aponeurotic covering of the canal between the adductors and the vastus internus exposed. The artery can be seen through the translucent fascia lata. If the saphenous nerve is seen it should be traced upward into the canal from which it emerges. If the nerve is not encountered the aponeurosis should be picked up and divided close to the adductor tendon. This opens the canal of Hunter. The vein, with the leg in this position, lies beneath the artery. The artery is cleaned and the needle passed from without inward to avoid the vein (Fig. 298).

The *indications* for ligation of the femoral artery are wounds, aneurism, operations upon tumors involving the artery, and as a preliminary step to amputation at the hip. In wounds, if the opening can not be dealt with by suture, ligation above and below is called for.

Popliteal Artery (Fig. 299).—The popliteal is the continuation of the femoral. It extends from the opening in the adductor magnus muscle to the lower margin of the popliteus muscle where it divides into anterior and posterior tibial. Throughout its course it lies in the popliteal space.

The popliteal space is a lozenge-shaped space behind the knee, occupying the lower third of the thigh and the upper fifth of the leg. It is bounded above the joint externally by the biceps; and internally by the semimembranosus, semitendinosus, gracilis, and sartorius. Below the joint externally are the plantaris and external head of the gastroc-

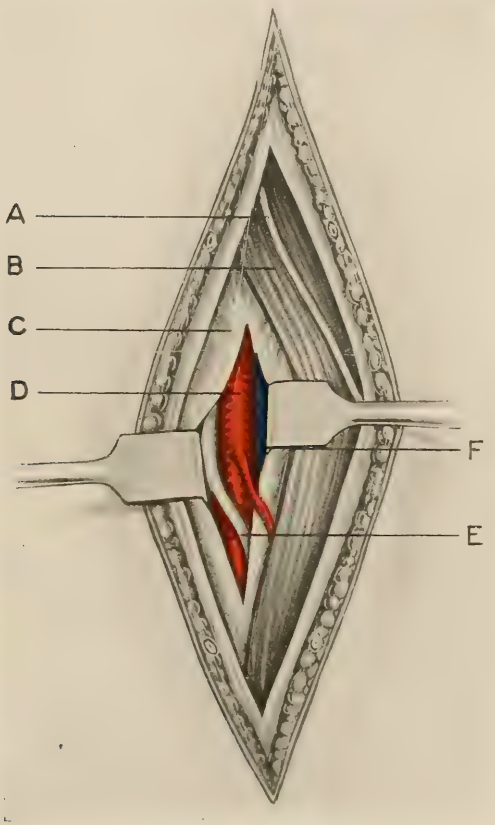


FIG. 298.—RIGHT FEMORAL ARTERY EXPOSED IN HUNTER'S CANAL.

A, Internal cutaneous nerve; *B*, sartorius; *C*, Hunter's canal (roof incised); *D*, femoral artery; *E*, internal saphenous nerve; *F*, femoral vein. (*After Bickham.*)

nemius; and internally is the inner head of the gastrocnemius. Its apex above is formed by the conjunction of the inner and outer hamstring muscles; below by the conjunction of the two heads of the gastrocnemius. The floor is formed by the femur, posterior ligament of the knee, tibia and popliteus muscle, all covered by the fascia lata. It contains the vessels, nerves, lymphatics and loose adipose tissue.

The internal popliteal nerve passes vertically down the middle of the space. The external popliteal nerve passes down on the outer side of the space close to the tendon of the biceps. At the bottom of the space are the vessels. The vein is the more superficial lying a little external to the artery and closely attached to it by connective tissue. Still more deeply, and close to the bone, is the popliteal artery, the direction of its course being from within downward and outward and crossing behind the internal popliteal nerve. It gives off a number of branches to the knee and the knee region.

To ligate the artery in its *upper part* the patient is placed on the affected side with the sound leg well flexed to prevent rolling into the prone position. A vertical incision is made along the outer margin of the semimembranosus muscle for 8 or 10 cm. (3 or 4 inches). The popliteal nerve comes into view. This should be retracted outward and the muscle inward, and the vessel will be found on the next deeper plane between the two. The vein lies on its outer side. They should be separated and the needle passed from without inward (Fig. 300).

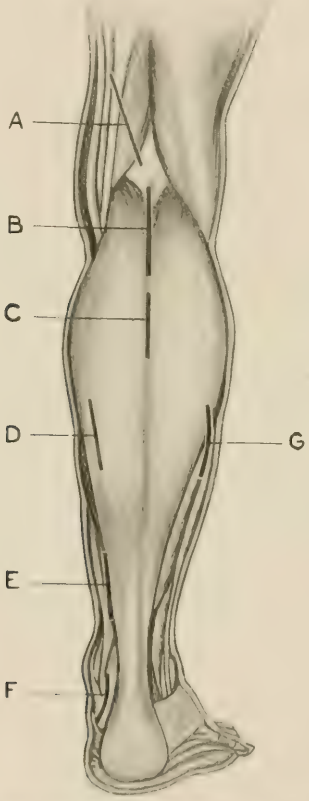


FIG. 299.—INCISIONS FOR EXPOSURE OF POPLITEAL AND POSTERIOR ARTERIES OF RIGHT LEG.

A, Incision for popliteal artery in upper part of popliteal space; *B*, exposure of popliteal artery in lower part of popliteal space; *C*, for posterior tibial artery in its upper third; *D*, posterior tibial in middle third; *E*, posterior tibial in lower third; *F*, posterior tibial behind internal malleolus; *G*, for exposure of peroneal artery in middle of leg.

To ligate the *lower part* of the artery, a 9-cm. (3½-inch) incision is made between the heads of the gastrocnemius. The external saphenous vein and nerve should be avoided. The muscle should be retracted. The popliteal nerve will first be discovered lying on the artery. It should be drawn aside. Here the popliteal vein is on the inner side and superficial to the artery. Separate them and pass the needle from within outward (Fig. 301).

The *indications* for operation are wounds and aneurism. Wounds are best treated by applying elastic constriction to the thigh, exposing the artery

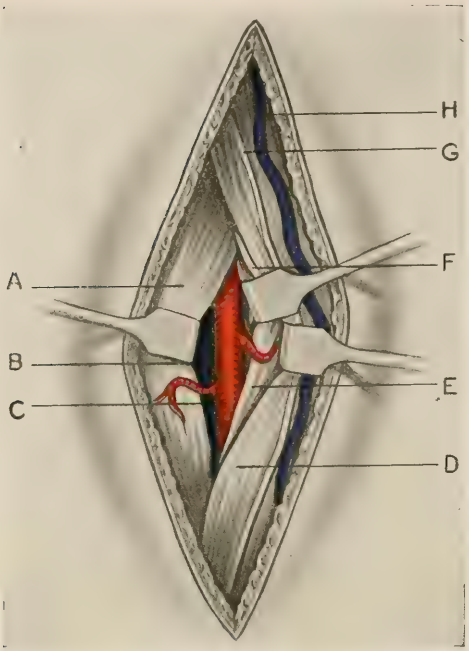


FIG. 300.—RIGHT POPLITEAL ARTERY EXPOSED IN UPPER PART OF POPLITEAL SPACE.

A, Adductor magnus; *B*, popliteal vein below and external to artery; *C*, popliteal artery; *D*, sartorius; *E*, semimembranosus; *F*, internal saphenous nerve; *G*, anterior branch of internal cutaneous nerve; *H*, internal saphenous vein. (*After Bickham.*)

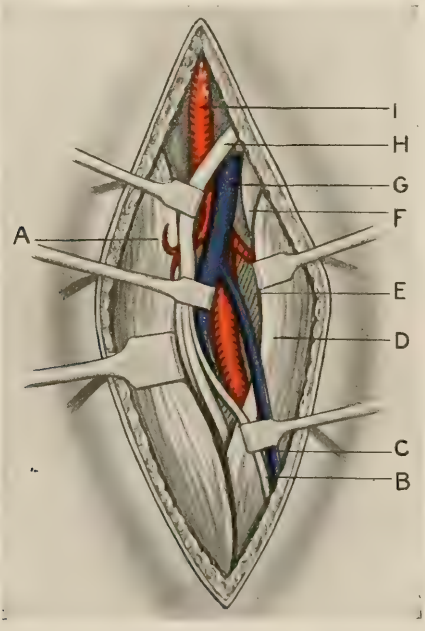


FIG. 301.—RIGHT POPLITEAL ARTERY EXPOSED IN LOWER PART OF POPLITEAL SPACE.

A, Inner head of gastrocnemius retracted inward; *B*, communicating branch of popliteal nerve; *C*, external saphenous vein; *D*, outer head of gastrocnemius; *E*, popliteus muscle; *F*, plantaris muscle; *G*, popliteal vein; *H*, internal popliteal nerve; *I*, popliteal artery. (*After Bickham.*)

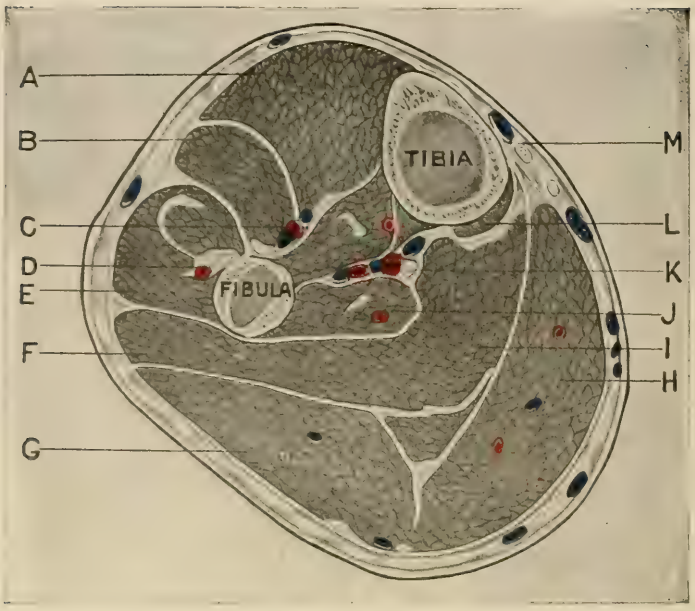


FIG. 302.—CROSS-SECTION AT UPPER THIRD OF RIGHT LEG.

A, Tibialis anticus; *B*, extensor longus digitorum; *C*, anterior tibial vessels and nerve; *D*, musculocutaneous nerve; *E*, peroneus longus; *F*, *G*, *H*, *I*, gastrocnemius; *J*, soleus; *K*, posterior tibial vessels and nerve; *L*, popliteus; *M*, internal saphenous nerve and vein.

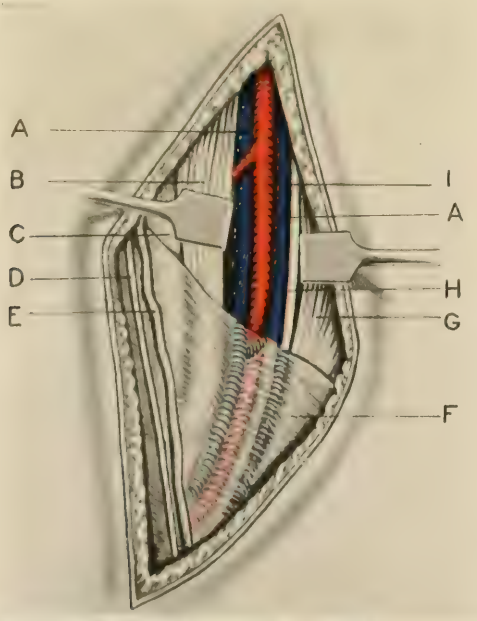


FIG. 303.—RIGHT POSTERIOR TIBIAL ARTERY EXPOSED BEHIND INTERNAL MALLEOLUS.

A, *A*, Posterior tibial venæ comites; *B*, flexor longus digitorum; *C*, tibialis posticus; *D*, branch of internal saphenous nerve; *E*, branch of internal saphenous vein; *F*, internal annular ligament; *G*, flexor longus pollicis; *H*, posterior tibial nerve; *I*, posterior tibial artery. *(After Bickham.)*

and ligating above and below the wound. Suture of the artery is difficult. Injury from fracture demands the same treatment. Injury of the leg with bleeding from posterior and anterior tibial, if the site of the bleeding can not be discovered, calls for exposure of the popliteal.

Posterior Tibial Artery.—The posterior tibial artery begins at the lower border of the popliteus muscle and passes down between the deep and superficial layers of muscles of the calf to a point midway between the tip of the inner malleolus and the heel, where it divides into external and internal plantar arteries.

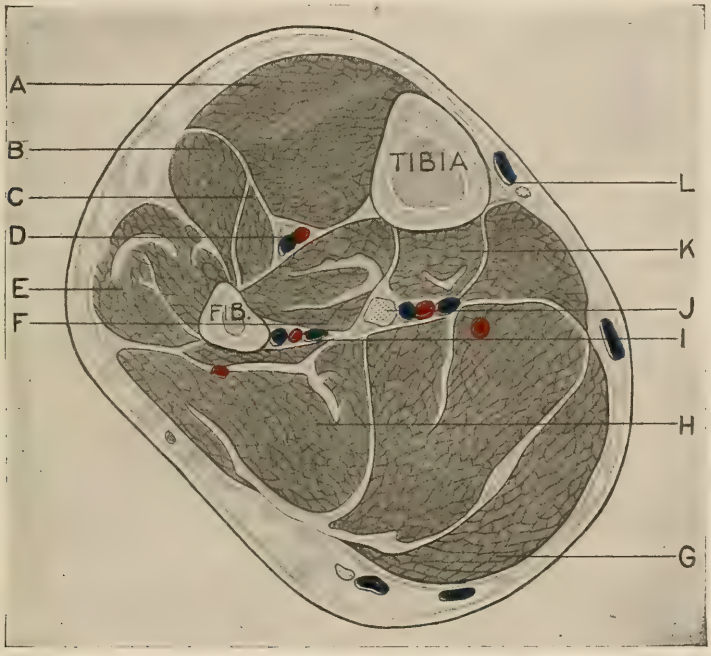


FIG. 304.—CROSS-SECTION AT MIDDLE OF RIGHT LEG.

A, Tibialis anticus; *B*, extensor longus digitorum; *C*, extensor pollicis; *D*, anterior tibial artery, vein and nerve; *E*, peronei; *F*, tibialis posticus; *G*, gastrocnemius; *H*, soleus; *I*, peroneal artery and veins; *J*, posterior tibial artery, veins, and nerve; *K*, flexor longus digitorum; *L*, long internal saphenous vein and nerve.

In its upper third, the posterior tibial lies deeply between the tibia and fibula, covered by the muscles (Fig. 302). In its middle third, it passes toward the back of the tibia; and in its lower third, it emerges to the inner side of the tendo Achillis and lies covered only by the skin and fascias. At the ankle it passes beneath the annular ligaments. In front of the artery from above downward are the tibialis posticus, the flexor longus digitorum, the posterior surface of the tibia and the internal lateral ligament of the ankle-joint. Above, the nerve is on the inner side. The nerve then crosses the artery, and in its lower part is on the outer side. Passing behind the inner malleolus, from the inner side of the astragalus inward, toward the tip of the inner malleolus, the structures are arranged in the following order: tendon of the tibialis posticus muscle, tendon of the flexor longus digitorum muscle, vein, posterior tibial artery, vein, posterior tibial nerve, tendon of flexor longus pollicis muscle. The line followed by the artery is from the middle of the internal malleolar fossa.

To ligate the posterior tibial artery *at the ankle*, the patient is placed recumbent with the thigh flexed and abducted and the outer side of the foot resting upon the operating table. An incision 5 cm. (2 inches) long is made

1.25 cm. (½ inch) behind the inner malleolus, the lower end of the incision curving forward at the tip of the malleolus. The annular ligament is discovered and divided. The incision should not be made any nearer the bone than 1.25 cm. (½ inch) lest the tendons of the tibialis posticus and flexor longus digitorum be exposed. The artery is easily felt and laid bare. It is close to the posterior surface of the tibia. It should be cleared of the venæ comites on either side. The nerve lies posterior and external and is avoided by passing the needle from behind forward (Fig. 303).

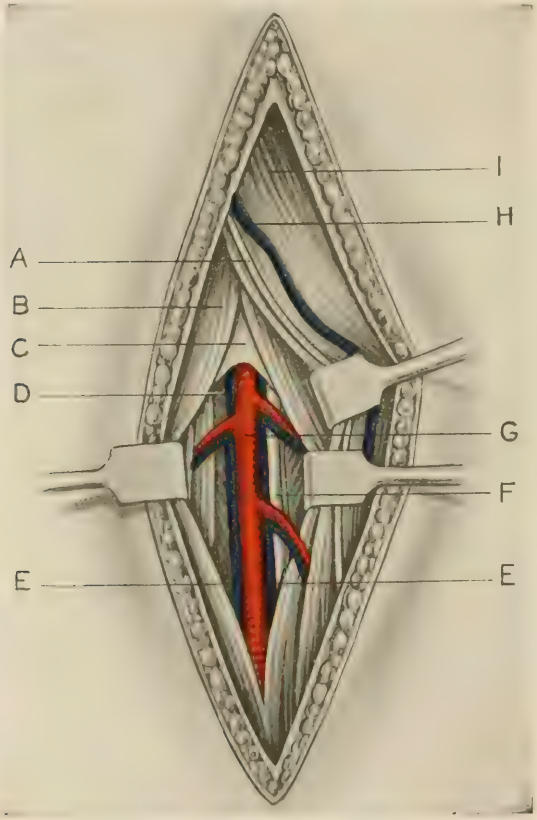


Fig. 305.—Right Posterior Tibial Artery Exposed in Middle Third of Leg.

A, Internal saphenous nerve; *B*, soleus, incised vertically and opening in muscle retracted laterally; *C*, deep intermuscular fascia; *D*, tibialis posticus; *E*, *E*, posterior tibial veins; *F*, posterior tibial nerve; *G*, posterior tibial artery; *H*, internal saphenous vein; *I*, inner head of gastrocnemius retracted outward. (*After Bickham.*)

To ligate *in the middle of the leg* (Fig. 304), the patient is placed in the same position as for ligation at the ankle. The inner border of the tibia is felt for, and an incision 10 cm. (4 inches) long is made parallel to it and 1.25 cm. (½ inch) behind. The incision is carried through the deep fascia. The gastrocnemius muscle should be retracted outward. The soleus muscle should be incised and retracted outward. The fascia lying in front of the soleus covers the artery; this should not be incised until the soleus is retracted (Fig. 305). Then carefully divide the fascia, expose the artery, and

pass the needle from without inward to avoid the nerve. If tendon sheaths are open they should be closed with a suture of fine chromic gut.

The *indications* for ligation are wounds and aneurism, both of which are best treated *in situ*.

Anterior Tibial Artery.—The anterior tibial is one of the terminal branches of the popliteal artery, arising opposite the lower border of the popliteus muscle. It passes forward to the front of the leg between the two heads of the tibialis posticus muscle, through an opening in the interosseous membrane. It passes down to the middle of the front of the ankle-joint

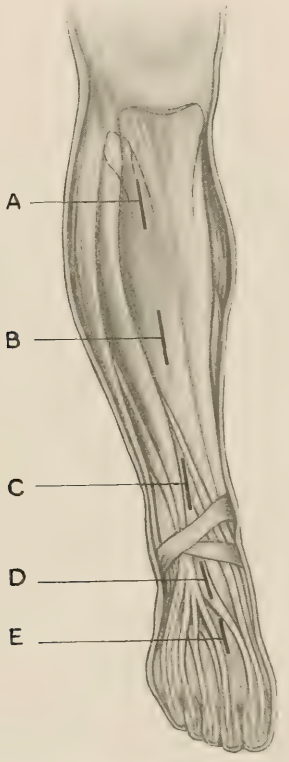


FIG. 306.—INCISIONS FOR EXPOSURE OF ANTERIOR TIBIAL AND DORSALIS PEDIS ARTERIES.

A, Incision for upper third of anterior tibial artery; *B*, for middle third of anterior tibial; *C*, for lower third of anterior tibial; *D*, for dorsalis pedis just below ankle; *E*, for dorsalis pedis in first interosseous space.

In its upper two-thirds the artery lies upon the interosseous membrane; in its lower third it lies upon the front of the tibia and then upon the ankle-joint. In its upper two-thirds the tibialis anticus muscle lies just to its inner side. Below, the tibialis anticus tendon lies to the inner side of the artery. Externally in its upper third is the extensor communis digitorum, at the middle third is the extensor proprius hallicis and at the lower third are the extensor communis digitorum tendons. In its lower two-thirds the tendon of the extensor proprius hallicis, coming from the outer side, lies in front of the artery or just to its inner side. In its upper two-thirds the artery is overlapped by the muscles. In its lower third it is covered only by the skin and fascias excepting where it is overlaid by the tendon of the extensor proprius hallicis and the annular ligament. It has two venæ comites. The anterior tibial nerve is external to the artery above. It approaches the artery and lies close to or in front of it in the middle of the leg, and continues close to its outer side as it passes under the annular ligament. The artery lies in a line beginning

at a point 2.5 cm. (1 inch) below the middle of a line between the head of the fibula and the tuberosity of the tibia, and passing downward to the middle of the front of the ankle. In the lower half of the leg a yellowish line of connective tissue 5 mm. ($\frac{3}{16}$ inch) wide lies between the tibialis anticus and the extensor longus digitorum, which serves as a guide to reach the artery (Fig. 306).

To ligate the anterior tibial artery in the *lower third* an incision 6 cm. ($2\frac{1}{2}$ inches) long is made in front of the artery ending below just above the level of the joint. The incision is 1.25 cm. ($\frac{1}{2}$ inch) external to the outer border of the tibia and just external to the tibialis anticus. It is carried down through the deep fascia. The tendon of the tibialis anticus is

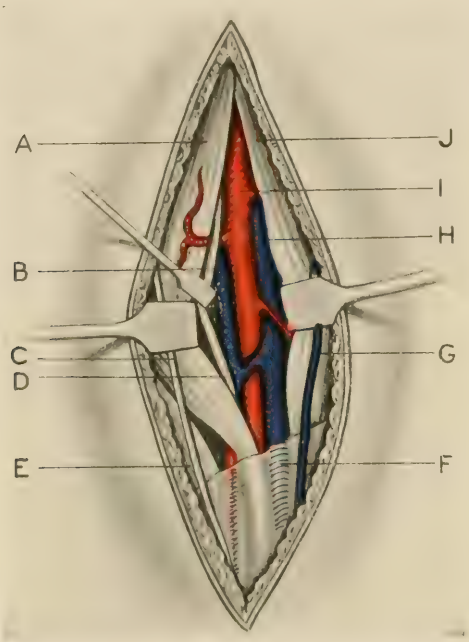


FIG. 307.—RIGHT ANTERIOR TIBIAL ARTERY EXPOSED IN LOWER THIRD OF LEG.

A, Extensor proprius hallucis; *B*, *H*, anterior tibial veins; *C*, inner branch of musculocutaneous nerve; *D*, anterior tibial nerve; *E*, extensor longus digitorum; *F*, annular ligament; *G*, branch of internal saphenous vein; *I*, anterior tibial artery; *J*, tibialis anticus muscle. (*After Bickham.*)

retracted inward. The tendons of the extensor proprius hallicis and the extensor communis digitorum are retracted outward. The artery and surrounding structures are relaxed by flexing the joint. The nerve is retracted outward and the needle passed between it and the artery. Tendon sheaths that are opened should be closed with a suture of fine chromic gut (Fig. 307).

To ligate in the *middle third*, the incision is made in the line of the vessel. The deep fascia is incised and the muscles retracted outward to expose the external surface of the tibia. The interosseous membrane is then exposed and followed outward to the vessel. In the middle of the leg the nerve lies in front of the artery. The nerve should be retracted outward, the artery separated from its veins, and tied.

To ligate in the *upper third*, an incision 8 cm. (3 inches) long is made in the line of the artery. The artery should be sought through the interspace

between the tibialis anticus and the extensor longus digitorum. The former muscle may be identified by making it tense by everting the foot; it should be retracted inward. The latter muscle may be identified by making it tense by strongly flexing the toes; it should be retracted outward. The interspace is followed down to the tibia and the interosseous membrane. Strong flat retractors are necessary for the muscle. The artery is found lying upon the interosseous membrane just internal to the nerve (Fig. 308).

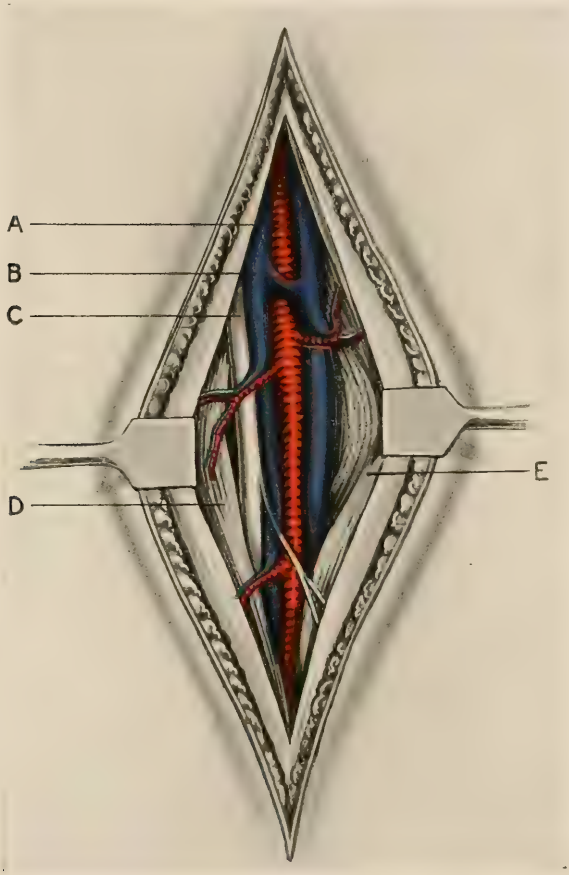


FIG. 308.—RIGHT ANTERIOR TIBIAL ARTERY EXPOSED IN UPPER THIRD OF LEG.
A, Anterior tibial artery; *B*, venæ comites; *C*, anterior tibial nerve; *D*, extensor communis digitorum muscle; *E*, tibialis anticus muscle. (*After Bickham.*)

The *indications* for ligation are aneurism and wounds. Usually ligation is required for wounds often caused by fracture. The best treatment for wound of the artery is rubber bandage anemia, exposure of the wound, and ligation *in situ*.

Dorsalis Pedis Artery.—This is a continuation of the anterior tibial artery. It begins at the middle of the front of the ankle-joint and passes directly to the first interosseous space, between the first and second metatarsal bones, where it divides into the dorsalis hallucis and the communicating arteries.

The artery has behind it the astragalus, scaphoid and internal cuneiform bones. The two venæ comites lie on either side. The anterior tibial nerve lies to its outer side above, but throughout most of its course it is in front or on the inner side. The artery is held against the bones by the deep fascia. It is overlaid by the inner border of the extensor brevis digitorum, the tendon to the great toe crossing the vessel in its lower third. The tendon of the extensor proprius hallicis lies to its inner side, sometimes slightly overlying the vessel. The inner tendon of the extensor longus digitorum lies to its outer side. The inner division of the musculocutaneous nerve is superficial and external to the vessel

To ligate the vessel, an incision about 5 cm. (2 inches) long is made in the line of the artery along the outer border of the tendon of the extensor proprius hallicis beginning above at the lower border of the annular ligament. The nerve should be identified. The artery is easily found and ligated. Tendon sheaths should be avoided and when opened they should be closed with a fine suture of chromic catgut.

The *indications* for ligation are wounds and traumatic aneurism. If it is done for wounds of the sole, the posterior tibial also should be ligated.

VEINS

Traumatism.—Traumatic injury to veins may cause a roughening of the inner coat, causing the deposit of a clot which may occlude the vessel and require the treatment for embolism.

Wounds of Veins.—Wounds of veins are even more easily amenable to treatment than wounds of arteries. A small wound of a large vein can be caught with a hemostatic clamp, and a *lateral ligature* of fine chromic gut applied (see Hemorrhage). This procedure, almost impossible in an artery, is easy in a vein because of the relaxed walls and low tension of the latter. Embolism and occlusion of the vessel is not prone to occur after lateral ligation. The avulsion of a branch of a large vein calls for the same treatment. The *suture* of wounds of veins is applied to wounds too large for ligation. The suture is best made with very fine chromic catgut. The manner of applying it must depend upon the nature and direction of the wound. The aim should be to leave no rough or foreign substance in contact with the blood-stream. The suture should be applied so as to appose intima to intima. If the through-and-through suture is tightly applied there will be a minimum of separation and exposure of the thread to the blood-stream. The sutures shown for arteries are the same sutures used in veins (see Arteries).

In the event of complete division of a vein, or laceration requiring resection, end-to-end *anastomosis* of the vessel is practicable. This operation is best done as follows:—The vein is compressed below and above the wound. The ends to be united are evenly trimmed. An everting mattress suture, bringing intima to intima, is then applied, as in arterial suturing (page 374). The needle should be the smallest round needle that will carry the finest chromic catgut.

The repair of *wounds of veins with loss of substance* is not difficult. It has been shown by Carrel and Guthrie (Compt. Rend. Soc. d. Biol. de Paris, June 22, 1906) that vessels may be patched with various substances. Peritoneum is especially useful for patching veins. Jianu (Jour. de Chir. de Bucarest, 1, 20, 1913) patched a torn femoral vein with a piece of the sac of a femoral hernia upon which he was operating when the accident occurred. Fatty tissue is used for the same purpose. It need only be placed against the opening in the vein and caught with a few stitches to the surrounding tissues. It is not absolutely necessary that it be sewed to the edges of the vein opening, as there is practically no blood-pressure in the veins. Grafts of fascia may be used for the same purpose.

Air Embolism.—The negative pressure, or suction, which is present in the great veins of the chest and neck during respiratory inhalation, may result in a rush of air into the opening in a wounded vein. This should be guarded against, particularly in the veins of the root of the neck when held open by tuberculous glands or other tumors. When in the course of an operation, or in treating a wound of this region, if the peculiar sucking sound is heard, the surgeon should at once press upon the opening in the vein to occlude it. If sufficient air has entered to cause embarrassment of the heart, the head should be lowered, fresh air or more oxygen should be admitted to the lungs, and artificial respiration should be resorted to if necessary. As a result of experiments on animals, Blair and McGuigan (Annals of Surg., 1910, vol. 52, page 471) found that the injection of adrenalin solution directly into the cavity of the right ventricle is a most effective means of causing contraction and overcoming the embarrassment of the overdistended ventricle. Cardiac massage is also of great value.

Phlebitis.—The treatment of phlebitis is important because of (1) the tendency to the formation of an infective embolus which may be swept to other parts, (2) the carrying of bacteria without embolism, (3) the infection of the tissues around the inflamed vein, and (4) the plugging of the vein with a clot, producing nutritive damage to the distal parts. For these reasons phlebitis demands serious consideration. The disease should be prevented as much as possible. (For preventive treatment and general principles of the treatment of embolism and thrombosis, see Embolism and Thrombosis, page 454).

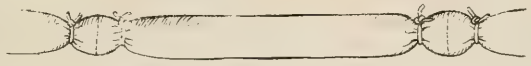


Fig. 309.—Resection of Vein for Phlebitis.
The infected segment is removed and the remaining stumps sterilized.

Non-infective phlebitis, if it is not traumatic, is usually the result of constitutional disease which produces changes in the walls of the vessel which may be designated as phlebosclerosis. This condition requires the same constitutional prophylaxis and treatment as arteriosclerosis. Another form is due to long-continued high pressure and stasis in the veins, observed in persons who stand much and walk little, such as motormen on trolley cars. This form of phlebitis invariably leads to varicose veins. The treatment is prophylactic avoidance of the causes.

Acute phlebitis is usually infective, although it may follow apparently clean operations or wounds. Many cases have not been proven infective. The treatment of phlebitis of a large vein consists in rest in bed for a month or more. The limb should be slightly elevated and kept quiet to prevent dislodgment of the clot. The part should be kept warm and clean. A flannel bandage, evenly applied, after the acute stage, will keep down the edema. It is doubtful if any application to the skin is of medicinal virtue. After six weeks, if there is still edema, massage may be instituted and the patient may begin to go about.

Postoperative phlebitis requires the same treatment. Posttyphoidal and puerperal phlebitis all demand the same general care. In all infective phlebitis, if the disease can be located, it is good surgery to ligate the vein above and below the disease and excise the affected segment. The stumps should be sterilized with phenol or iodin. This may be done as an aseptic operation without infecting the wound (Fig. 309). If excision of the vein is not practicable, but ligation is, then the diseased segment should be freely

laid open between two ligatures, and the clot washed out. This treatment is of great importance in infective thrombosis of the lateral sinuses. In the internal saphenous vein resection finds its most easy application.

Varicose Veins.—The first step in the treatment of varicose veins should be the discovery of the cause and its removal if possible. There is always some provoking influence either local or general. Defective heart action, constipation, nutritive defects, autointoxication, standing much with little exercise, thrombotic or other venous obstruction are among the causative factors to be dealt with. If varicose veins are associated with edema of the part from which they return, it is a sign of obstruction of the deep veins; and to operate upon such varicose veins is a serious mistake. Obstruction of deep veins often results in varicose dilatation of the superficial vessels without edema; in which event the integrity of the latter is very important. Varicocele and hemorrhoids are discussed elsewhere; likewise varicose ulcers and eczema. The most common varicose veins outside of these are found in the lower extremities.

In *varicose veins of the legs*, having known causative factors, much can be done to improve the local conditions. The nourishment and tone of the parts can be improved by cold bathing and upward rubbing. Giving the limb a cold douche for a minute or more once or twice a day, followed by upward massage for fifteen or twenty minutes is of much service. If the discomfort and swelling of the veins persist unabated a flannel bandage smoothly applied from the toes to the knee will give relief. The elastic stocking serves the same purpose. These things have the disadvantage that they take the place of the natural muscular and elastic resilience of the limb and tend to aggravate the weakness of the veins. When once begun they must be continued. If used they should be left off as much of the time as possible. A better means of securing relief is by elevating the part. If the patient at some of his work can sit with the affected leg elevated to the level of the pelvis or higher or if he will exercise the muscles of the leg and thigh the circulation will be much improved. Motormen, desk-clerks, and other people, whose work requires them to stand without moving for long periods, are most susceptible to varicose veins of the leg. Such persons should often flex their knees and thighs, and raise their weight on the balls of the feet to promote venous circulation and prevent the disease. If the patient with varicose veins of the leg will lie on his back once daily and elevate the legs vertically against a wall for twenty minutes while gentle massage toward the trunk is applied, followed by a flannel bandage or elastic stocking, much comfort will be secured.

Varicose veins which do not extend above the knee are usually amenable to treatment by simple measures just described. A vein lying close beneath the skin, if the skin is much thinned, particularly if it is situated in front of the leg, should be ligated and removed because of the danger of rupture and hemorrhage. When a varicose vein does burst the bleeding is easily controlled by pressure. *Eczema* which is common in legs having varicose veins is remedied best by measures which improve the circulation and help the varicose disease. Ichthyol ointment (10 to 20 per cent). is of service.

Varicose veins extending above the knee and involving the internal saphenous vein are best treated by operation. It should be borne in mind that this disease persists because there is a giving way of the valves of the superficial veins of the leg, so that the veins of the lower part of the leg have to sustain the weight of an unnaturally high and uninterrupted column of blood. If the weight of some of this column can be taken off help is gained. Many methods of doing this have been devised. A pad made of a water bag

or air bag, placed over the internal saphenous vein just below or just above the knee and held in place by an elastic garter gives relief in many cases. The blood can return by way of the deep veins even if all of the superficial veins are compressed. It is not pressure from below caused by the returning blood but pressure from above caused by hydrostatic weight that gives the symptoms.

So long as the valves in the internal saphenous veins do their work, varicose veins are not of much trouble, but when they must carry the weight of the long saphenous column, operative relief is called for. These valves may be tested by elevating the leg to let the blood run out, then compressing the saphenous at the saphenous opening and allowing the patient to stand. When the pressure is taken off if the valves are ineffective the blood from above will drop at once into the vein and fill it.

The *operative procedures* for the treatment of varicose veins offer a large measure of relief, but while they cure the varicose veins, defective circulation often continues because of the mischief which the disease has done and because of the inadequacy of the remaining vessels. If all of the superficial veins are varicose, and all are taken out, there often still remains circulatory disturbances due to an associate diseased condition of the deep veins. of some of the superficial veins are varicose, and are taken out, there is a strong probability of the same disease existing in other veins in an earlier stage.

Operation often gives a cosmetic cure, no more varicose veins can be seen, but the extremity is cold and cyanotic, and eczema develops just the same as though the veins were there. While operation is always advisable, and will cure the varicose veins in the sense that anything that is removed is cured, still so far as restoring the leg to a normal state goes, too much should not be expected in all cases. I say this as a result of observation of many hundreds of cases which have been subjected to operation but not cured.

In many persons, particularly in cases of those whose general health is good and who are not old, or in those in whom a causative factor has been overcome operation may give a permanent cure. The surgeon is justified in recommending operation in most cases, because some relief, if not complete cure, can always be promised. The conditions calling especially for operation are: (1) long saphenous insufficiency; (2) thin-walled veins which may rupture; (3) veins that have already ruptured; (4) chronic intractable varicose eczema; (5) chronic varicose veins; (6) localized varicosity, not due to deep obstruction, in order that the patient may escape being regarded as physically unfit on account of varicose veins; and (7) painful varices. Operation should not be done if infective phlebitis exists unless it is done to remove the inflamed vein or to treat thrombosis.

The best material with which to tie varicose veins is fine chromic catgut. After operation the patient should be kept in bed for two weeks, and be allowed to walk at the end of three weeks. Several operations will be described, two or more of which will often be required in the same case. The best operations are those which take into account the fact that the disease is one in which the veins suffer from the hydrostatic pressure of the column of venous blood of the body.

Ligation of the internal saphenous vein (Trendelenburg's operation) is the operation of the greatest value in this disease. This operation alone suffices to give relief in most cases. It can be done under local anesthesia. The vein lies on the inner and front side of the thigh as it approaches the saphenous opening. It is situated beneath the superficial fascia and lies upon

the deep fascia covering the adductor muscles. It passes obliquely upward, forward and outward. It should be ligated just before it enters the saphenous opening (Fig. 310). If the vessel can be seen or has been marked with stain its exposure is simple. The saphenous opening can usually be felt with the finger. In the absence of these guides, an incision about 6 cm. (2½ inches) long should be begun just below the saphenous opening about 2.5 cm. (1 inch) internal to the artery and 5 cm. (2 inches) below Poupart's ligament and pass downward and inward. Or the incision may begin 5 cm. (2 inches) below the middle of a line on Poupart's ligament between the artery and the spine of the pubes, and be carried downward and inward. The vein is found under the fat, lying on the fascia lata. It should be ligated in two places with catgut cut between and the wound closed. By ligating the vein 3 to 5 cm. (1 or 2 inches) below the opening, a number of small vessels are avoided. This operation may be done alone or it may be combined with the following operation.

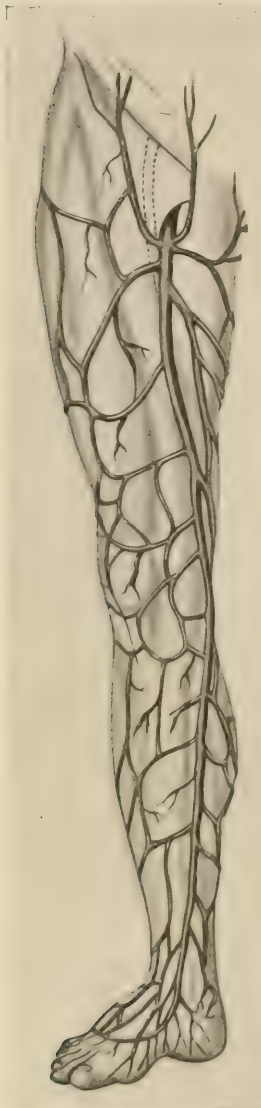


Fig. 310. Internal Saphenous Vein.

Showing point of ligation and tributary veins. Femoral artery indicated by dotted lines.

The excision of varicose veins is a procedure which radically cures the disease in the veins operated upon and improves the conditions in the adjacent veins. It requires time and patience, and should not be entered upon lightly. The strictest asepsis should be maintained. Infection of the wounds is fraught with the danger of septic embolism. When the operation is once started the number of enlarged veins discovered is often greater than was presumed. The surgeon should be content to remove only those which are distinctly varicosed. To be sure of the location of the vessels it is often advisable to have the patient stand up, and the course of the veins can be marked with 10 per cent. silver nitrate solution, applied with a hair brush. This may be done a day or two before the operation. It leaves a brown line which is not washed off in the cleansing. Or after the cleansing, an anilin pencil, washed in sterile solution, may be used. Usually the increased venous pressure caused by ether anesthesia is sufficient to bring out the veins. The incisions are best made directly over the veins and parallel to them. The operation should begin at the upper part of the field. An incision is made upon the vein, the vessel isolated, clamped in two places and cut between the clamps. The lower clamp is then picked up and used as a tractor to draw the vein down as it is dissected free. A small sharp knife should be used. It is necessary to dissect the vessel away from the skin by carefully cutting the rather dense fibrous tissue which connects them. This separation of the skin

should be done before the vein is lifted up. After the skin is incised, it is lifted up with fine forceps, catching the subcutaneous tissue if possible so as not to damage the skin. The vein is easily freed from its bed when once the skin is separated. Branches should be clamped and divided as fast as they are exposed. The skin incision is prolonged as the operation proceeds. It may become 25 to 50 cm. (10 to 20 inches) or more in length (Fig. 311).

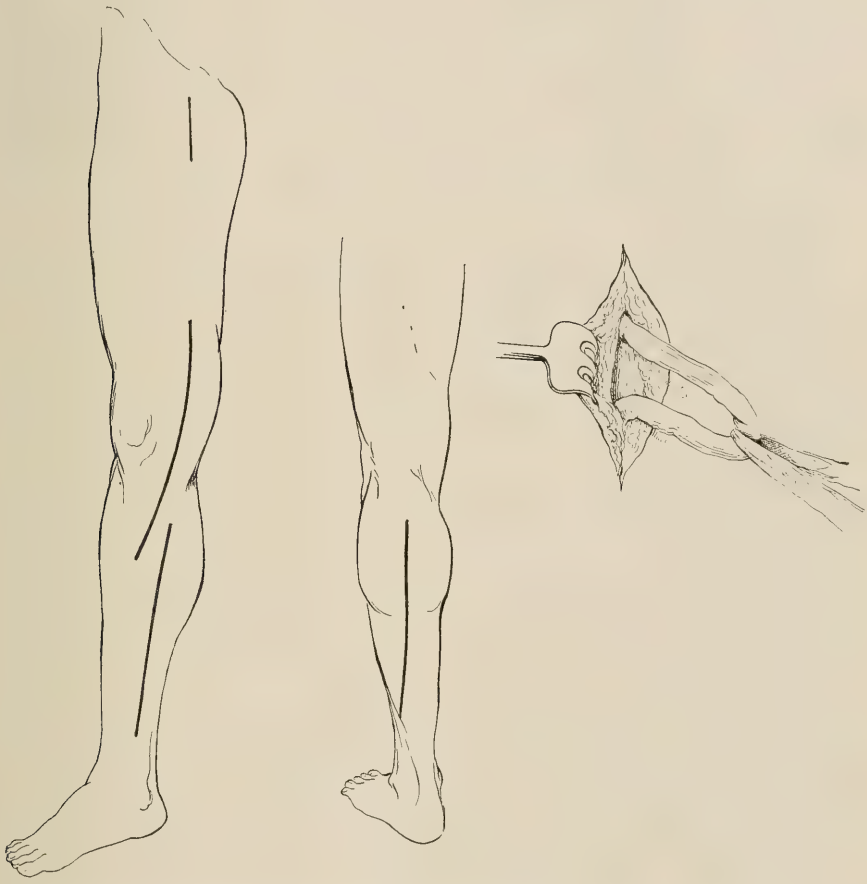


FIG. 311.—LIGATION AND EXCISION OF VARICOSE VEINS.
Showing usual incisions to expose veins. Vein drawn out of wound by means of a loop of gauze. (*After Mayo.*)

Large connecting veins should be clamped, and dissected out. Incisions may communicate with the first skin incision or not as the case demands. Other enlarged veins here and there require separate incisions. Often a group of vessels, making a spongy tumor covered by thinned skin, will require attention. In such cases it is almost impossible to dissect free the skin without opening the veins. Here it is best to plan the incisions in such a way as to remove an ellipse of thinned skin with the vessels, dissecting up the skin on either side and ligating all branches and trunks entering the group. Small isolated varicosities may simply be ligated through a small incision, the ligature being carried around them with the aneurism

needle or the eye-end of a heavy curved needle. They should be ligated in two places and cut between.

The wounds following extensive removal of varicose veins are best closed with a continuous suture of some non-absorbent material such as paraffined silk or celluloid thread.

Multiple ligation of varicose veins is of value in cases in which varicosities are widely scattered but are not sufficiently enlarged to demand excision. Each vein or segment is cut down upon and exposed through an incision 1.25 cm. (½ inch) long. The vein is freed from the skin with a few strokes of the point of the knife. The ligature carrier, aneurism needle, or eye-end of a curved sewing needle carries a double thread around the vessel. The vessel is tied in two places, and cut between. The wound is closed with one or two stitches. Unless these vessels are cut the circulation is prone to become reëstablished after the ligature is absorbed. Enough multiple ligations and division of the vessels has practically the same effect as excision.

Segmentary subcutaneous excision is practised by making a short incision over the vein, ligating in two places and dividing between; this is repeated every 8 or 10 cm. (3 or 4 inches); a long pair of dressing forceps with a strong bite is inserted in the upper wound and pushed alongside of the vein until it emerges from the next wound; it grasps the end of the segment of vein beside which it lies and pulls it back through the wound. This is repeated until all the segments are removed. The branches are torn loose by the operation, but bleeding is controlled by the immediate application of a compressing dressing.

Extirpation by inversion begins by ligating the vein at its highest limit; dividing it below the ligature; and then passing into the vein a long bullet probe carrying two strands of the heaviest paraffine silk thread. This probe is passed down inside of the vein until it will go no farther, but preferably not more than 20 or 25 cm. (8 or 10 inches). An incision is then made down upon the end of the probe, the vein is exposed and clamped, and a longitudinal incision is made in the vein 1 cm. (⅜ inch) above the clamp. This incision should be about 6 mm. (¼ inch) long. Through it the thread carried by the probe is brought out and tightly tied around the vein below the opening. The vessel is then divided just above the clamp, the probe removed, and the upper end of the thread emerging from the upper opening in the vein pulled upon. This operation results in inverting the lower end of the vein into the vein. Traction is continued and the vein is pulled out of the upper wound inside out. The branches are torn off, but pressure controls the bleeding.

Subcutaneous enucleation was devised by C. H. Mayo. It requires an instrument which consists of a steel ring, 7 mm. (¼ inch) in diameter, attached at an angle to a long handle like a blunt curette. The vein is exposed in the thigh and divided, the proximal stump tied, the distal stump is passed through the ring and grasped by traction forceps. The ring is then pushed along under the skin, tearing loose the branches of the vein as it goes. After it has passed down 13 or 25 cm. (5 or 10 inches), the skin is incised, the vein pulled out, rethreaded in the ring, the instrument introduced in the last incision, and the enucleation continued.

Circumcision of the leg is an operation devised by Schede for the cure of varicose veins. The object is to remove the hydrostatic pressure from the vessels. It consists in carrying an incision completely around the leg on a horizontal plane below the knee, about at the junction of the upper and middle thirds of the leg. As the varicose veins are exposed they are ligated in two places and cut between. All vessels down to the deep fascia are

divided. The circular incision should be carried down to the deep fascia but not through it. When all of the vessels between the deep fascia and the skin have been divided, the wound is closed. *Spiral circumcision* is even more effective than the horizontal operation.

Injection treatment consists in exposing the internal saphenous vein just above the knee, ligating and dividing it below the ligature; into the distal opening of the vein is injected with a syringe a mixture of 1 part iodin, 1.6 parts iodide of potash, and 100 parts distilled water. The injection is slowly continued until 30 to 50 c.c. of the fluid is thrown in. The vein is then tied and the incision closed. Another method is to make two openings in the vein, one above the knee and another in the upper part of the thigh, or one at the knee and another at the ankle. The fluid is then injected into the stump of the vein in the lower wound and flows out of the vein in the upper wound. The proximal stump in the upper wound should be tied. This fluid causes the lining of the vein to throw out an exudate which obliterates the lumen.

Ligation of femoral artery, below the point where the deep femoral is given off, by diminishing the blood-pressure and the amount of blood flowing through the vessels of the leg, has been of service in some cases.

Phlebotomy.—For the operation of phlebotomy or venesection, the skin in front of the elbow is prepared as for operation. The patient lies or sits and grasps an object in his hand upon which to close the fist. A band is tied about the upper arm to produce venous obstruction. The patient extends the forearm, and squeezes with his fist to cause the flexor muscles to become prominent. The surgeon places his left hand under the patient's elbow, and makes gentle pressure upon the vein with his thumb. Either the median basilic or the median cephalic is chosen. The thumb steadies the vein just below where the surgeon cuts it. The vein is opened by transfixing it with a small, sharp-pointed knife. The thumb is removed and bleeding allowed to proceed. If the patient is sitting in a chair, the bleeding should be stopped as soon as faintness begins or sooner. This is done by removing the constricting band, and applying to the wound a firm pad of sterile gauze, held on with a bandage. The arm should be supported at a right angle in a sling for a week.

The more approved method of drawing blood is by **venous puncture.** This is done with a hollow needle as for infusion or medicinal injection. No incision is required. The needle is passed through the skin into the vein, and the blood flows out of the needle. This is in all respects a more simple and better operation than venesection and allows an accurate collection and measurement of the blood (see Intravenous Infusion, page 346).

Angioma.—Angioma is properly a disease of the blood-vessels. It is made up largely of dilated capillaries and veins. Plexiform angioma (cirsoid aneurism) is dealt with under the treatment of diseases of arteries. Small capillary *nevi* or "*mother's marks*" require no treatment if not enlarging, unless treatment is applied for cosmetic purposes. Larger nevi or "*port wine stains*" call more urgently for treatment. These diseased areas may be excised completely and the wound closed. If the area is too large to close by simple suture a plastic operation may be done either with sliding flaps or grafts (see Plastic Operations, Vol. III). Small nevi may sometimes be cured by shutting off their circulation and causing coagulation by subcutaneous suture (Figs. 312 and 313). Radium, thermoradiation (Vol. III), liquid air, and liquid carbon dioxide are effective (see Skin Diseases, Nevus, page 842).

Electrolysis is successfully applied to diseases too large to remove or which involve irremovable structures. This operation should be done with every aseptic care. Needles connected with the positive and negative poles are thrust into the tumor. Coagulation takes place about the positive pole.

The needles should be insulated except at the point. The points should be from 2.5 to 7 cm. (1 to 3 inches) apart. A current of from 25 to 75 milliampères is used. The mechanical traumatism also causes coagulation. The treatment is continued for ten minutes; then the current is momentarily increased to loosen clots from the needles and the needles are withdrawn. A moist antiseptic compressing dressing is applied. The treatment should be given every two weeks until the disease is cured.

Cavernous or spongy angioma, made up largely of dilated veins, requires the same treatment as cirsoid aneurism. The tumor should be circumscribed by an incision into healthy tissue, vessels ligated individually and *en masse*, and the tumor excised. The wound, if too large to be sutured, may be closed by plastic operation (*q. v.*). In locations not permitting excision, electrolysis offers prospects of cure. It should be applied the same as in angioma. Subcutaneous suture is also applicable to these tumors (Fig. 313).

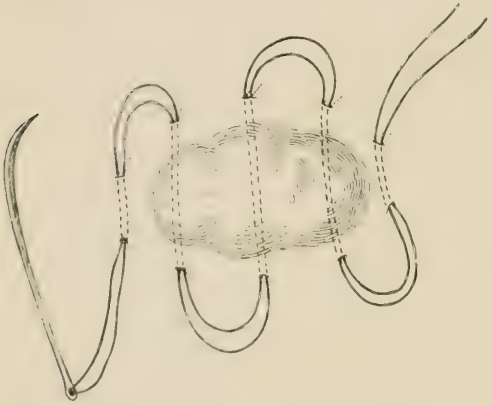


FIG. 312.—TREATMENT OF ANGIOMA BY SUTURE WHICH SHUTS OFF THE BLOOD SUPPLY.
Showing double suture passed.

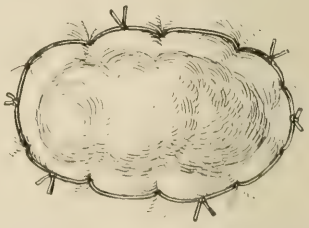


FIG. 313.—SHOWING DOUBLE SUTURE CUT AND TIED TO SHUT OFF BLOOD SUPPLY TO ANGIOMATOUS TUMOR.

Thrombosis and Embolism.—The *prevention* of these conditions should always have the surgeon's consideration. When arteritis or phlebitis exists the parts should be kept as quiet as possible. Massage or rough handling tend to cause the enlargement and dislodgment of clots. Thrombosis and embolism, following operations, should be guarded against. Prolonged extreme flexion of joints should not be practised. In the lithotomy position, the flexion of the hip and knee should not be to the extreme degree in old persons. Coagulation of blood is apt to take place when the heart becomes very weak or the circulation retarded. After operations there is danger because vessels have been ligated and clots are present. The danger is especially great following the major pelvic operations. Following hysterectomy, for example, the heart should not be allowed to become weak for a minute lest the clot in the uterine vessels extend into the iliacs. The circulation should be kept going briskly with the help of respiration. If it flags, ten or twenty deep breaths should be taken every half hour, and there should be some massage of the limbs to prevent stasis. If there is acute anemia, fluids should be added to the blood, and the head of the bed should be lowered. The lowered-head position is one of the best preventives of thrombosis, as the blood flows constantly toward the heart from the pelvic veins. So important is this that it is a wise practice after operations in-

volving the ovarian, uterine or iliac veins, to keep the foot of the bed elevated 40 or 50 cm. (18 inches) for the first two days, and then gradually lower it during the third day. Danger of embolism and thrombosis may be determined by testing the *coagulability* of the blood. The coagulability of the blood is retarded by the administration of 5 or 6 Gm (75 to 90 grains) of *citric acid* daily for from one to three days. This is capable of retarding the coagulation time from one to three minutes.

Embolism of the pulmonary artery may be prevented by these measures. Embolism coming from hemorrhoidal veins or from varicose veins of the leg is always to be guarded against. Metastatic infections from wounds are also responsible for this condition. The first sign of obstruction in the iliac or femoral veins may be discovered by measuring the circumference of the legs; and upon finding evidence of obstruction, treatment should be applied.

The *treatment of embolism* and *thrombosis* depends upon the size of the vessel and the danger of gangrene. In a healthy patient the expectant treatment is generally advisable. In a candidate for gangrene something more may be done. If the clot can be located, the vessel may be opened by a longitudinal incision, the clot withdrawn, and the vessel closed by suture as already described. This operation has usually been followed by reformation of the clot at the same site, if due to local thrombosis. If a septic embolus is located, the vessel may be tied above and below the embolus and the disease removed.

Reversal of the circulation is possible. In aseptic occlusion of the *femoral artery*, threatening gangrene, it is best to open the artery and remove the embolus. It is entirely feasible also to implant the artery into the femoral vein, preferably below the saphenous opening. The valves of the vein do not obstruct a current having arterial pressure, and the vein takes on an arterial function. This was done successfully in man by Wieting of Constantinople (Deutsche Med. Woch., July 9, 1908). His case was one in which the patient had had a leg amputated for gangrene due to arteriosclerosis. The other foot and leg had become cold and livid. The femoral artery was divided and sutured into the femoral vein through a lateral opening. The foot and leg became warm and the signs of impending gangrene disappeared. The case of Doberauer (Presse Médicale, Sept. 11, 1907) suffered *axillary embolism*. The clot was removed fifty-two hours after obstruction occurred, when gangrene of the fingers and ischemic contraction of the muscles of the forearm had begun. Again the clot reformed. The wound in the artery was opened and the clot again removed. Three hours after the operation, the obstruction had again developed and the gangrene advanced. Then Doberauer made an anastomosis between the axillary artery and vein above the obstruction. This was successful. The veins of the arm pulsated with blood, and twelve days later the case was reported as cured. This is the first successful case of the kind.

In the case of a patient with an embolus, swept from the heart and lodged in the common *iliac artery*, which was leading to dry gangrene of the leg, J. B. Murphy exposed the femoral artery just below Poupart's ligament. The artery was opened by a longitudinal incision and found completely occluded by thrombus. With delicate forceps a bifurcated clot was withdrawn from below upward, coming from the femoral and the profunda. Blood followed, showing that there was some collateral circulation. Pressure was then made below the wound, and attempts made to dislodge the clot above. Forceps, irrigation, and the insertion of a catheter 19 cm. (7½ inches) brought out only dark blood clots and grumous débris. No arterial

blood flowed. After passing catheters and probes a distance of 47.5 cm. (19 inches) up into the artery, suddenly a gush of bright arterial blood swept the vessel clean. Temporary pressure was made above the wound to occlude the vessel and the wound closed. This operation was done four days after the embolus had been arrested in the iliac artery, and the leg was cold up to 20 cm. (8 inches) above the knee. After the operation the line of demarcation receded so that amputation was made 10 cm. (4 inches) below the line of bleb formation and the flap survived. This was an aseptic embolus and should have come to operation immediately after its occurrence. Opening the artery just below or at the obstruction, and removal of the embolus, should result in restoration of the circulation and cure.

H. Matti (Correspondenz-Blatt f. Schw. Aerzte, Dec. 6, 1914) operated on a man of seventy with sudden *embolism of the femoral artery*. No pulse could be felt below Poupart's ligament. He opened the femoral artery and removed embolic plugs above and below. Although thirteen hours had elapsed, the circulation was restored except in two toes which later were amputated.

Ligation and *excision of pelvic veins* for the treatment of *septic thrombophlebitis* of puerperal origin has become an accepted surgical procedure. The mortality following the operation is high although not so high as that in the unoperated cases. As commonly seen in the ovarian, hypogastric and other veins of the pelvis, the vein is best exposed by abdominal section. It is seen to be swollen and boggy. The peritoneum should be incised, and the vein tied above the clot, or a ligature placed above and below the site of disease, and the segment of the vein removed. The remaining stumps should be touched with iodin, and the abdomen closed. If there is evidence of infection outside of the vein provision for drainage should be made. (See Puerperal sepsis, Vol. III.)

The *treatment of venous occlusion* from thrombosis usually need only be tentative. The part should be elevated and treated according to the measures given for gangrene. If gangrene does not occur, after two weeks when the clot has become organized, massage may be begun. If an aseptic clot has formed in the large vein and is accessible, it is good surgery to make a longitudinal incision into the vessel and remove the clot. In the case of septic thrombosis the vein should be tied above the thrombus, or below and above the thrombus and the diseased section removed. This operation is successfully done upon all of the great veins. In pelvic infection with thrombosis of the ovarian or uterine veins the operation is of great value. In puerperal pyemia ligation of the ovarian veins alone is of service. Thrombosis may sometimes be discovered in branches of the portal vein; in which event ligation of the branch above the disease prevents its entrance into the general circulation, and assures its cure by absorption or by abscess formation. Often the thrombosed vein can be felt through the vagina, but even when it can not the persistence of rigors and other symptoms call for the transperitoneal exposure of the pelvic veins and ligation above the disease. The hypogastric veins may also require attention. (For further information concerning the treatment of thrombosis and embolism, see Gangrene, page 315.)

Fat Embolism.—This condition may be prevented by care to ligate veins, which are open in the presence of fat, and by draining wounds in which much fat is exposed. After the making of such a wound, if fat appears in the urine or the first signs of pulmonary embolism appear, it should be assumed that broken-down fat is finding its way into the open mouths of veins, and the wound should be opened and abundant provision made for drainage so that

the fat shall have free escape. In the case of fractures, in which the fat comes from the marrow of bones, perfect immobilization should be secured. If the fat comes from damaged subcutaneous tissue, displaced bone should be replaced or the fracture region exposed and the fat area drained. It should be borne in mind that the entrance of the fat is not an instantaneous process but goes on gradually, and it is never too late to apply local treatment. Usually the process takes place under some pressure, for which reason drainage is indicated.

When the pulmonary artery becomes plugged with fat, and respiration fails, artificial respiration should be used. By this, together with oxygen inhalations, the crisis may be tided over.

Operation for *embolism* of the *pulmonary artery* is something more than a surgical curiosity. Trendelenburg studied these cases clinically, operated on the cadaver and upon animals, and then operated upon patients who were suffering with this grave condition (Beiträge zum Zentralb. f. Chirurg., No. xxxv, 1908). The artery lies at the second left interspace, and is covered by the pericardium. Behind it is the superior vena cava. The ascending aorta is in front of both arteries.

Complete compression of the artery can be tolerated for from forty-five seconds to two minutes; beyond that time death occurs. In the case of nine patients with pulmonary embolism, reviewed by Trendelenburg, two died in from one to two minutes; in the other seven cases, an interval of from ten to sixty minutes elapsed before the patients died. In most of the cases there were fifteen minutes at the disposal of the surgeon for operation.

Trendelenburg marked a transverse incision on the second rib, a vertical incision on the left side of the sternum and resected 10 or 12 cm. (4 to 4¾ inches) of the second rib. A vertical incision is made through the pleura and into the pericardium at the level of the third rib. The vessels lie behind the sternum; they are drawn forward, and a rubber tube passed behind the pulmonary artery and some forward traction made. This should all be done in one or two minutes. Enough compression should then be made to close the pulmonary artery. As compression with the rubber tube is made, the artery is incised, to the extent of 1 cm., special flat forceps introduced, and the clot withdrawn. This must be done within forty-five seconds. The wound in the artery is then temporarily clamped by a curved lateral clamp and sutured at once.

If the clot has not all been removed the forceps may be passed into the branches. Traction on the rubber tubing may be relaxed as soon as the lateral clamp is applied.

The embolus has been reached also by incising the right ventricle and sucking the obstruction from the pulmonary artery by a special pump, hemostasis being secured by compressing the vena cava.

Two cases operated upon were pulseless during the operation; they revived quickly after the extraction of the thrombi from the pulmonary artery, some of which were 34 cm. (13 inches) long. The loss of blood from the artery has been small. Patients have survived the operation as long as five days. Of the cases so far reported by Trendelenburg none have been cured. Heart failure during operation, hemorrhage and pneumonia have been the chief causes of death (Deutsche Zeitschr. f. Chir. No. 44, 1907). Patients operated upon by other surgeons have lived as long as sixteen days. W. Meyer (Annals of Surg., vol. 58, 1913) has fully discussed this subject.

In *thombosis of the portal vein*, ligation has been practised in cases in which infection has entered the mesenteric veins from such conditions as suppurative appendicitis.

Anastomosis between the portal vein and the vena cava (Eck's fistula) is a successful laboratory experiment. It is compatible with life. As yet it has not been applied in human surgical therapeutics (Bull. Johns Hopkins Hosp., Feb., 1912, xxiii, No. 252). Bernheim and Voegtlin believe that this operation, which they have done on dogs, may be expected to give relief in cirrhosis of the liver (see Ascites, Vol. II, and Venous Anastomosis, page 377, Vol. I).

Determination of the Coagulability of the Blood.—In considering surgical treatment it is often important to know the coagulability of the blood. This is especially necessary in conditions in which the possibility of hemorrhage or thrombosis has to be considered. In diseases of the liver and in hemophilia the coagulability of the blood may be abnormally low and hemorrhage continue from small openings in vessels. In certain blood conditions with high specific gravity of the blood and high viscosity coagulation may occur so easily that slight traumatisms to the vessels or retardation of the blood-stream may cause thrombosis or embolism.

The surgeon should inquire for a family history of hemophilia. The simplest way to test the coagulability of the blood is to observe the coagulation time of a little blood in test-tubes. The coagulametric technic of M. Blach is as follows: 1 c.c. of blood is drawn from a vein into 4 c.c. of an isotonic solution (sodium citrate, 1 Gm.; sodium chloride, 7 Gm.; and distilled water, 400 c.c.). A set of test-tubes containing from 4 to 3 c.c. of an isotonic solution of sea salt (seven per thousand) is used. To each of these tubes is added a 5 per cent. solution of calcium chloride in amounts of 0.5 c.c., 0.4 c.c., 0.3 c.c., 0.2 c.c., and 0.1 c.c. Then 0.2 c.c. of the citrated blood is added to each tube. Each should contain 4 c.c. of fluid. In twelve to fifteen hours, the coagulation process is complete. The citrate prevents the blood from coagulating by inactivating the calcium in the blood. Adding traces of calcium restores the coagulating power. This may be estimated by the ratio between the amounts of calcium and of citrate: Control tube 1, no calcium; tube 2, 4; tube 3, 2; tube 4, 1.33; tube 5, 1; tube 6, 0.8. Time is not regarded. In normal conditions, coagulation begins in tube 3, index 2 (threshold of coagulation) and finishes in tube 5, index 1. In children under ten, it usually begins with index 4 and ends with index 1.33. In case of a predisposition to hemorrhage, both threshold and finish are retarded. This technic reveals also any excessive tendency to coagulation.

Further information can be obtained by pricking the ear with a lancet and counting the half minutes before the blood stops spontaneously. With blood drops 1 cm. in diameter, hemostasis occurs normally in from two and a half to three and a half minutes. The physiologic or pathologic condition of the capillaries is revealed by slight constriction of the arm, such as is applied for venesection, which may induce a punctate hemorrhagic appearance below, showing that the capillaries are extra fragile.

In order to profit by the information derived from these tests, subcutaneous injection of 20 or 40 c.c. of normal human or animal blood-serum should be made when the blood does not coagulate normally. This corrects conditions in acquired hemophilia so that operative hemorrhage need not be feared. In familial hemophilia, the operation should be postponed until the condition can be corrected by injections of blood-serum every two months for a year. By this means it is thus possible to modify the blood so that it will coagulate in thirty or forty-five minutes, instead of three, six or twelve hours as before. Calcium chloride by the mouth or in injections can not be relied upon to increase the coagulability of the blood.

The form of blood anomaly in which coagulation is not much retarded, but in which there is no retraction of the clot, is the type of a true hemorrhagic diathesis. The hemorrhages are more liable to occur spontaneously than with hemophilia. Such is the case in acute purpura. A subcutaneous injection of 20 or 30 c.c. of human blood forty-eight hours before the operation is most effective in preventing hemorrhage in these cases. This supplies the hematoblasts which are lacking. It is useful likewise in the hemorrhagic tendency with liver disease.

In cases in which the tests show excessive coagulability of the blood, thrombosis menaces, and ether and chloroform should be avoided as they injure the blood and may bring on thrombosis. In such cases blood-serum should never be injected. It must be remembered that losses of blood increase the coagulating power of the blood. Blood can be rendered less coagulable by citric acid. Chantemesse prescribes it in the daily dose of 12 or 18 Gm. of citric acid diluted in a large amount of water. Sodium citrate in similar doses might answer the purpose. Subcutaneous injections of saline or glucosed isotonic physiologic solution might be useful or a 47 per thousand solution of sugar by the drip method. P. E. Weil (Presse Médicale, Apr. 12, 1917) believes that it seems logical to utilize the anticoagulating action of herudin, the active principle of the heads of leeches.

LYMPHATIC SYSTEM

WOUNDS AND RUPTURE OF LYMPHATIC VESSELS

The lymph in its return from the extremities has so many channels that wounds of the lymphatic vessels in the limbs demand no especial treatment aside from the treatment of the general wound. It is sometimes observed that a flow of lymph is present in a wound of the groin or axilla, but as soon as the wound is healed the lymph-flow ceases without evidences of lymphatic obstruction. The important thing is that such wounds should not become infected.

Wounds of the thoracic duct are more serious. It is not an uncommon thing for this duct to be wounded in the neck near its termination. This accident has not uncommonly occured as the result of operations in that region. Suture of the duct is difficult because of its small size. A complete closure of such a wound by suture need not be attempted. If the duct has been completely divided the two ends should be approximated by a couple of lateral sutures of fine chromic catgut. No attempt to make a fluid-tight anastomosis need be made. It suffices if the two openings are approximated to one another. In the event of a lateral nick of the duct, a suture is not necessary, although if the surgeon find it practicable a single suture, not involving the lining of the duct, may be applied.

It is a fortunate thing that the natural tendency of these wounds is to heal, whether they are sutured or not. Of vastly more importance than suturing the duct is that the surgeon should address himself to the general health and asepsis of the wound of the surrounding tissues. Infection of the thoracic duct or the subclavian vein is a serious accident. Clean wounds of the neck in which the thoracic duct is opened should be closed excepting their lower part where an opening for the discharging chyle should be left. All adjacent connective-tissue spaces should be closed. A light gauze packing should be introduced to serve as a drain to conduct off the chyle and to make a slight obstacle to favor the entrance of some of the fluid into the vein-side of the wound. Infiltration of the tissues will take place if the outlet from the wound is too much obstructed, or if there are large open spaces in the bottom of the wound. Fatal mediastinal pressure and abscess may result from this complication. If the wound is kept clean, chyle continues to escape while granulation is going on, drainage may be dispensed with after the second day; and shortly the wound closes. After the wound is lined with granulations more and more pressure should be made on the sinus to oppose the escape of the chyle, and thus encourage its entrance into the subclavian vein or its entrance into the blood by way of collateral channels. I can see no sufficient reason for following the conventional injunction to keep these patients upon an exclusive proteid diet. Pathologic rupture of lymph-ducts is treated upon the same principles as are applied to wounds (see Neck, Vol. II).

A wound of the *receptaculum chyli* should be sutured the same as a wound in a vein. Suture of such a wound is not imperative as it may be expected to take the same course as a wound of the thoracic duct.

Lymphorrhagia.—A flow of lymph occurs from wounds or pathologic ruptures of the lymph-channels. The treatment of these ruptures has been described above. Obstruction to lymph-ducts by tumors, inflammations,

Filaria sanguinis, or disease of the ducts themselves, resulting in the escape of chyle which accumulates in cavities, sometimes requires treatment. Chylous ascites and chyle cysts are such conditions. The accumulation of chyle in these cases should not be drawn off unless it becomes very tense and produces pressure, interferes with bodily functions because of its mechanical presence, or has become infected. If aspiration is done there is always danger of infection. So long as the fluid remains in the body some is being reabsorbed. As the chyle is essential to life it should be preserved as much as possible. In the meantime the general health of the patient should be improved by every attention to hygiene; any removable cause of the disease should be eliminated; and the hope indulged that the leak will cease. If such a case is losing a serious amount of chyle, I can see no reason why an accessible vein should not have a valvular opening made in it to carry off the lymph.

Lymphangitis.—Lymphangitis may involve the lymph spaces or the lymph trunks. In either case rest of the limb is imperative. The part should have applied the local treatment of cellulitis. Large warm compresses are of value. The hard red streaks, running up a limb from an infected wound and signifying lymphangitis, should be painted with four or five coats of tincture of iodin. Ichthyol and mercurial ointment are also used locally. The infection is prone to break through the lymphatics and produce suppuration. Abscesses should be opened early. Always of the first importance is the free drainage and aseptization of the original wound from which the lymphatic infection developed.

Lymphadenitis.—*Acute lymphadenitis* requires first the treatment of the infective focus giving rise to the disease. Pain in the glands, if due to acute swelling, is controlled by cold applications. If pain is not present hot fomentations are of service. The overlying skin may be treated with mercurial ointment, ichthyol, or silver ointment. The occurrence of suppuration calls for incision.

Chronic lymphadenitis is due to some chronic source of infection, such as chronic gonorrhea, osteomyelitis, or decayed teeth, or to some constitutional disease such as tuberculosis or syphilis. In the case of local disease, the lymphadenitis subsides when the cause is removed; and no local treatment of the glands is called for unless suppuration occurs. In the case of syphilis the treatment is constitutional.

Tubercular lymphadenitis requires constitutional treatment, the same as is applied to tuberculosis elsewhere (page 276). Tuberculin (page 257) and heliotherapy (Vol. III) seem especially efficacious in this condition. It is possible that the tuberculous glands in the young represent the mild infection whereby immunity against tuberculosis is acquired. For many years surgery has made the mistake of focussing too much attention upon the glands themselves. It is not the tuberculous glands so much as it is a human being who needs treatment, and in whom the infected glands are incidental. First hygiene, then antituberculous measures and then surgery should be the rule. The operative removal of these glands is still an unsettled question. Surgical thought and practice fluctuate. Most surgeons have passed through the stage of operation and back again to non-interference. My own belief is that they should not be operated upon so long as they are small and quiescent. But so long as they exist, efforts to improve the hygiene of the patient should not be relaxed. If the disease is not improved by hygiene and antituberculous treatment, and the glands become offensively large, they may be removed.

Many persons, apparently well, have palpably enlarged lymphatic glands. It is not necessary that all enlarged glands be removed. Not all

are tuberculous. Broken-down and suppurating glands should be taken out. The same is true of tuberculous glands which have suppurated and left discharging sinuses. The scar will be less and time will be gained, if tuberculous glands are removed before these later degenerative changes have taken place. The *x*-rays hasten the healing of whole or broken-down glands. *X*-ray treatment has more to offer than has operation in most cases.

Tubercular glands are most commonly removed from the neck. Their removal is not difficult as each gland is found enclosed in a capsule from which it is easily shelled out. Each gland has running into it from behind its nutritive vessels which are often so small as not to require ligation. Each gland is connected to the glands above and below by the lymph-vessel on which it lies. These vessels serve as guides to the chain of glands. In dissecting out these little tumors the surgeon must be satisfied to stop somewhere because, go as far as he will, there always lies another gland beyond. It is a good plan to stop when the largest glands have been removed or when the lead carries him into regions where the operation threatens to become complicated. Where deep glands lie along the course of the vessels glands will be found adherent to the sheath of the vein. Here, instead of avoiding the vein, there will be less danger of wounding it if the surgeon exposes it so that he knows just where it is. In other words, in the case of glands lying along the main vein, it is better to dissect the vein away from the glands than to dissect the glands away from the vein.

Lymphatic Obstruction.—Whether it is due to a closure of the lymph-channels by inflammation, tumor or other outside pressure, or to *Filaria sanguinis hominis*, lymphatic obstruction produces an induration of the extremity by filling the lymph-vessels and spaces with dammed-back lymph. *Lymphedema* and *elephantiasis* result. The treatment of this condition is the removal of the cause and the restoration of the circulation of lymph. This is often impossible in which event other measures must be applied. Massage, bandaging, elevation of the part and hot applications followed by cold douching are all of service. The internal administration of tincture of the chloride of iron has been of benefit in many cases.

Of *operative procedures*, that of W. S. Handley (Lancet, March 14, 1908, page 783, and British Med. Jour., April 9, 1910) is based upon the principle applied by Lambotte (Semaine medic., 1905, page 19). It is of service in a large proportion of cases. Two lines of silk of a U-shape are placed under the skin, one on either side of the limb. In the case of the arm a V is used. One of the lines lies on the front, the other on the back of the arm. The median openings should be just above the elbow. The two upper openings are connected by transverse threads passing around the shoulder. From the posterior upper opening back of the shoulder threads may radiate over the scapular region (Fig. 314). The operation has been called *lymphangioplasty*. It should be done with the strictest asepsis.

A thick soft silk thread (No. 12), longer than twice the length of the limb to be operated upon is threaded in a long blunt-pointed probe. A small cut is made at the lowest part of the disease; the probe is passed into the wound and upward in the subcutaneous connective tissue; when it has reached its limit another incision is made and the probe pulled out; it is then reinserted and passed upward again; another incision is made and the probe with its thread pulled out. This operation is carried on until the thread is passed into healthy tissue above the disease. The thread is thus buried under the skin. The other half of the thread is buried in a similar manner parallel to the first and connected below by a subcutaneous loop. The operation is repeated on the opposite side of the limb. The free upper ends of the thread are cut short and tucked into the wounds. All of the wounds are

then closed by sutures. The limb should be kept elevated much of the time after the operation. The number of these subcutaneous drainage channels may be regulated as the case seems to demand.

The result of the operation is that the lymph finds its way to these new canals, and limbs which had been indurated with lymph become, for a time at least, soft and pliable. The operation has been applied with much success to the legs and in *brawny arm*. In the distressing swellings of the arm due to the obstruction caused by secondary deposits following cancer of the breast, and following the scar tissue of operation, this treatment gives relief in a considerable proportion of cases.

In true *elephantiasis* the operation of Handley is of little value. It gives improvement for a few days while the patient is in bed and the limb elevated,

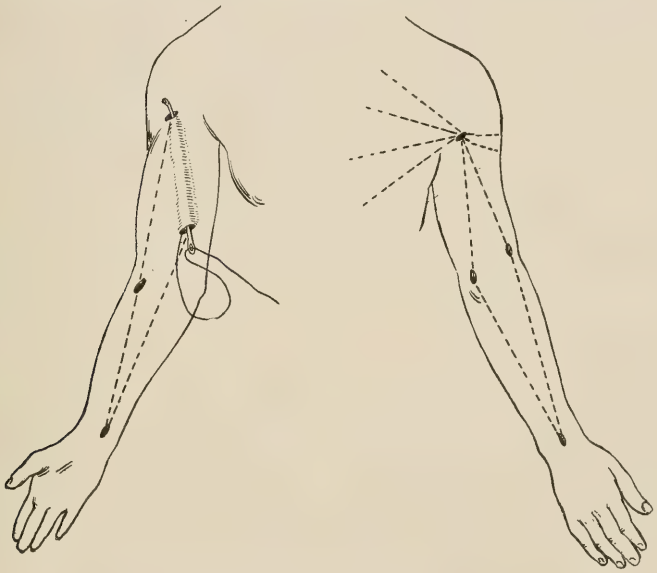


FIG. 314.—LYMPHATIC DRAINAGE (LYMPHANGIOPLASTY OF HANDLEY).

but as soon as the patient begins to walk, or at least within three weeks, the swelling returns as bad as ever. This is because the buried thread becomes surrounded by a capsule of dense fibrous tissue which ultimately penetrates it and leaves a line of scar tissue containing the disintegrated remnants of the thread.

The same principle is applied also in *ascites* and in edema of the face and other parts.

Deep *lymphatic drainage* may be obtainable also by effecting a free communication between the superficial and deep lymph-channels. The fascia lata, it is known, forms a barrier between the superficial and deep channels. Acting on the suggestion of O. Lanz of Amsterdam, a long incision on each side of the leg is made down to the muscle, the wound retracted, and a strip of deep fascia 5 cm. (2 inches) wide dissected from the covering of the muscle throughout the length of the wound. A strip of the subcutaneous connective tissue is also removed. In elephantiasis below the knee the incisions extend from the knee to the ankle. If the leg and thigh are both involved, two long incisions should be made on either side, two in the thigh and two in the leg. Such operations may be done in the leg, thigh, forearm and upper arm. After removing the strip of fascia from the muscle, a

septum between the muscles should be discovered and opened so that a cleft down to the bone or deeper tissues is made. A broad-based flap of the subcutaneous tissue should then be cut, tucked into this cleft, and held with a few sutures. Even though this flap is not used, the simple denudation of the muscles will suffice in many cases.

Lanz (Zentralb. f. Chir., 1911, S. 3) also devised an operation which consists in incising the deep fascia, separating the fibers of the muscles, and trephining the bone in several places to expose the marrow. In all of these operations the skin wounds should be closed and primary union secured.

Amputation of lymphedematous limbs is a last resort. Excision of lymphedematous tissues is done sometimes with good result. But usually, unless the excision removes all of the diseased tissue, there is strong probability of recurrence of lymphorrhea or of the edema; and even though all of the edematous tissue is removed, unless the operation is an amputation, recurrence is apt to take place.

Elephantiasis remains still an unsolved surgical problem. All treatments are tentative, doubtful of result, or mutilating. *Elephantiasis of the scrotum* is only cured by removal of all of the diseased tissue; if any remain, it seems to cause a spread of the disease to adjacent tissues. The same may be said of the leg. The disease has been treated by removing all of the tissues external to the muscles from the foot to the knee in a case in which the disease was confined to that part of the limb. The decorticated leg was grafted with skin and a cure secured. Only the radical operation, which removes all of the disease, is worth doing; the removal of a wedge of tissue is followed by recurrence.

Castellani (British Med. Jour. No. 2, 1908) claimed good results in elephantiasis of the lower extremities by keeping the patient horizontal, bandaging the limb with an elastic bandage, and making daily injections of *fibrolysin*. This drug is a mixture of thiosinamin and salicylic acid. From 2 to 4 c.c. in water is injected in the affected parts or in the gluteal region. The pressure of the bandages must be evenly and firmly distributed. From three to six months of this treatment produces pronounced results. At the end of that time the redundant skin may be excised in long strips and the wounds closed. The patient should wear elastic stockings to prevent recurrence. The best results have been had in the old chronic cases.

Lymphangiectasis (Varicose Lymphatics).—This condition is caused by the same factors as produce lymphedema. It is treated upon the same principles as are applied to nevus or angioma. It appears usually in the groin, scrotum or upper thigh. The dilated vessels should be dissected out if possible. This dissection should go well into sound tissue particularly above, otherwise the place of the obstruction may not be removed and lymphorrhea will result.

Lymphangioma (Lymphatic Nevus).—The treatment of this condition is the same as that of varicose lymphatics. The dilated vessels and cavernous spaces should be removed. If the diseased area is small and circumscribed it may be excised like any other tumor. *Macroglossia* is treated by excision of the front part of the tongue by a V-shaped incision. The use of electrolysis is indicated if excision is impossible. This is applied in the same manner as in angioma. If complete excision cannot be done it may be possible to excise the upper part of the disease, cutting into sound tissue. This operation in acquired lymphatic obstruction may remove the obstacle. The destruction of the tumor with the cautery is also a recognized procedure.

Infective Lymphoma (Hodgkin's Disease, Malignant Lymphadenoma, Pseudoleukemia).—Inasmuch as this disease is due to a specific micro-

organism, the *Bacillus hodgkini*, its treatment must be that addressed to an infective disease. Without treatment the disease is fatal within five years; and up until the discovery of the cause of the disease but a small proportion of cases had been cured by any means. I. L. Yates and C. H. Bunting (Jour. Am. Med. Assoc., July 12, 1915), who have contributed the modern knowledge of this disease, have laid down definite rules for treatment.

Removal of the source of infection is the first step. If the infection is primarily in the neck, tonsils, nose, teeth, eyes, ears and accessory sinuses should be looked to and cured of any local disease. In all neck cases the tonsils should be suspected, and a complete tonsillectomy done. If the primary infection is not from the head but in some other part of the body, the portal of entrance should be sought, with the lymph channels as the clue, and any local nidus of disease eradicated. In treating the primary local focus, it should be understood that the disease is of a virulent infective character and the danger of spreading the infection considered.

Removal of the hypertrophied lymphatics should be undertaken as the next step. In the neck the dissection should be complete. The glands which are closely adherent to the internal jugular vein often will require removal of the vein with them. It is particularly important that the glands which lie at the angle of junction of the internal jugular and subclavian vein be removed. The veins may have to be sacrificed. Invasion of the mediastinum, if possible, must be prevented. The whole wound should be treated with iodin to destroy free organisms. In the axilla and groin the same methods must be pursued. Unfortunately when infection reaches the groin, it is associated with retroperitoneal involvement which militates against successful extirpation.

When recurrence takes place after excision of glands it may be early and rapidly fatal; or it may not appear for a year, and then be very chronic. Such chronic recurrences may be removed if the operation is done promptly.

The *treatment of pseudoleukemia with x-rays* should be undertaken by an experienced radiologist. The applications should be made to the localized enlargements. It can not be predicted how the case will react. In some the glandular swellings subside and may be controlled indefinitely; in other cases they subside and new enlargements appear in the deeper parts; in other cases no effect is secured; and in others the disease seems to be aggravated. Enough favorable reaction has been secured to warrant a trial of the *x*-rays in all cases. The cases which manifest toxic symptoms after the first treatment need not be given up, but should be treated by smaller dosage. By weekly applications these patients may often be kept well for many years.

Treatment with *x*-rays is beneficial. It should be applied to the wound from the day of operation. The applications should be as intensive as the skin will tolerate.

Vaccine treatment naturally must be considered in an infective disease. Autogenous vaccines are probably most hopeful, but thus far no positive results can be attributed to this treatment. Serum treatment seems to be of service in some cases.

Conversion of the diseased tissue into fibrous tissue takes place when the disease recedes. Any agency which will bring about this change should be sought for. Thus far the *x*-ray and improvement of the general health are the only agencies which have been observed to effect this change.

Hygienic treatment is most important because the resistance of the patient is found to be a positive determining factor in the progress of the disease. Outdoor air, good food, cheerful environment and everything that contributes to good health is helpful.

All cases are seen to be benefited by anything that improves the general health. Even slight mental or physical depression is followed by recrudescence of the disease. The same general hygienic measures as are applied to tuberculosis are useful here.

Medication is of doubtful value. Arsenic and benzol have not proved effective. Injections of salvarsan cause temporary improvement, and then recurrence as bad as ever. Injections of mixed toxins of erysipelas cocci and *Bacillus prodigiosus* are of doubtful efficacy.

Cure may be regarded as accomplished when there is a normal blood picture and no glandular recurrences five years after the last manifestation of disease.

Leukemia.—This complex disease of the blood is of surgical interest because of its some time association with enlargement of the spleen. In *myelogenous leukemia*, *x*-rays, applied to the spleen, the femur and the tibia in many cases causes at least an abatement of the symptoms; although arsenic medication often has the same effect. Benzol, administered by mouth or rectum (2 Gm. in 50 Gm. of olive oil thrice daily) causes a remarkable diminution of the leukocytosis. It should be stopped as soon as the number of leukocytes begins to diminish as its action continues for some time.

In *treatment of leukemia by the x-ray*, all of the long bones of the body should be treated. The dose should be regulated to produce the desired effect without toxemia. Daily treatments should be given. Intervals without treatment should not occur. The body should be mapped out and the rays applied to each bone successively. The spleen should not be exposed to the rays during the early treatment, but should receive attention after treatment of the bones has been well started. Treatment should continue not only until the leukocyte count becomes normal but the differential blood count also and until myelocytes have disappeared from the blood. Differential counts should be made frequently; and at least once a month after a cure seems to have been attained. Upon the appearance of signs of relapse, treatment should be resumed. Arsenic should only be used if the patient is compelled to discontinue the *x*-rays. The cases of the lymphatic leukemia seem to respond better to *x*-ray treatment than the myelogenous cases. In acute cases the *x*-ray seems to be of no value. The *x*-ray should be applied to the spleen with care because it causes hemolysis; and for this reason the red blood cells must be watched, and when indicated, treatment must be discontinued and measures for restoring the blood instituted.

The *transfusion of blood* from a healthy person, near of kin, has given encouraging results in some cases.

Malignant Metastases in Lymph-nodes.—The cure of cancer depends upon the removal of the primary growth and of secondary deposits. Usually the site of secondary deposits is the lymph-nodes. Sarcoma, excepting lymphosarcoma or lymphadenoma, transmits its secondary deposits through the blood-vessels, and lymph-nodes are not prone to become secondarily involved. In operating for carcinoma, after the primary growth has been removed, the operation is not complete unless the adjacent distal lymphatics are exposed and removed, if enlarged; or, if removal is easily possible, it should be done whether they are enlarged or not. Carcinomatous metastases developing in lymph-nodes subsequent to primary operation should be removed, provided the removal of all of them is possible. In some cases a partial operation is justifiable even when the surgeon is confident that all of the disease cannot be eradicated. Such an operation or the conditions which seem to call for it should be governed by the same rules as are laid down for the treatment of inoperable malignant growths (page 331).

DISEASES OF BONES

CONTUSIONS

Contusions of bones injure the overlying soft tissues and the periosteum. If the bone structure itself is injured the injury is really a fracture. Such injuries are important because of the diminished local resistance which is created, and because such areas may become infected by bacteria from the circulating fluids. Such contusions should be treated by rest of the part. If a hematoma is present and is sufficiently large to cause painful pressure, it should be evacuated. Later when acute symptoms have subsided, massage will hasten the absorption of the products of the injury. The application of the ice-bag to injuries of bone is not to be recommended. Its only use is to cause a contraction of blood-vessels to check bleeding if there is evidence of a continuous subcutaneous hemorrhage.

PERIOSTITIS

Acute periostitis requires the treatment already given for inflammations (see page 228). When the products of infective nontuberculous inflammation lift up the periosteum, immediate incision is demanded. A subperiosteal collection of pus gives rise to necrosis of bone over the area from which the periosteum is lifted, and the sooner the pressure is relieved the less wide will be the necrosis.

Chronic periostitis, if due to syphilis or tuberculosis, requires the treatment given for those conditions. If due to other infection of a mild type or to other irritation, it is best treated by the methods already given for chronic inflammations. The surgeon is always on the safe side in cutting down upon the disease, and dealing directly with it. Even though no drainage is required, the local reaction excited by the operation is of therapeutic value.

Chronic osteoplastic periostitis in which a hypertrophy occurs, forming a tumor, often of peculiar shape, should be treated by radical operation. The hypertrophied tissue should be removed by knife and chisel.

OSTEITIS

Osteitis, exclusive of that of osteomyelitic origin, requires treatment usually for the necrosis which it produces. Treatment of necrosis is described under the heads of the conditions which produce it. Acute inflammation of non-medullated bone demands the same treatment as osteomyelitis.

Denuded Bone.—It sometimes occurs that the soft parts are torn from a bone, and the surface is left denuded. The bone becomes dry and remains in this state. Nothing grows over it. This is common in scalping accidents. Unless tissue can be made to grow on the bone superficial necrosis will take place. Granulations may be made to grow upon such a surface by boring holes through the outer table into the diploë. This is an old method, lost in antiquity. E. J. Mellish (Annals of Surg., vol. 40, 1904) quotes Vance who used it in 1777. It was employed to promote healing of cranial denudation caused by scalping by Indians. Some surgeons have used a trephine and

either removed a superficial button of bone or allowed the granulations to spring from the circle cut by the instrument. A gouge has been used to cut grooves. The simple boring of holes, as practiced by Vance, suffices (Fig. 315).

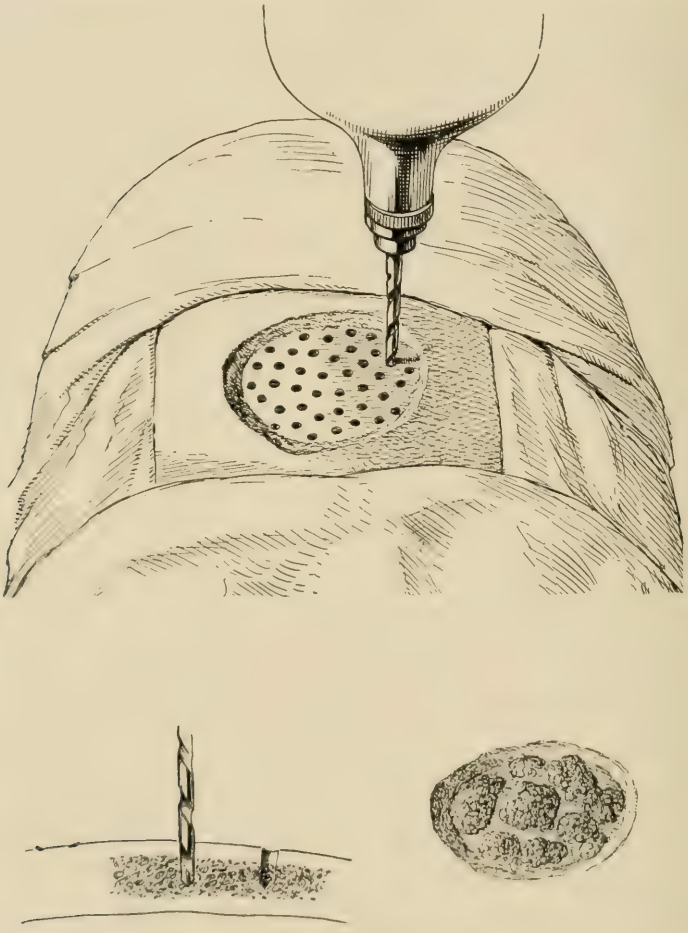


Fig. 315.—Boring Outer Table of Dry Denuded Bone Surface to Promote Granulations.

CARIES AND NECROSIS

Osteomyelitis, tuberculosis, syphilis and actinomycosis are the specific causes of inflammatory bone destruction, and treatment will be found under those heads. Removal of the dead bone is usually necessary. The methods of doing this and the treatment of the resulting cavity are described under operations on bones. **Phosphorus necrosis** should be prevented by sparing human beings the necessity of working for a living at making phosphorus matches for somebody else's profit. As soon as the necrosis is discovered the patient should leave off work in the phosphorus industry, although in most countries her place will promptly be taken by some other victim of the industrial struggle. It is best to wait until the sequestrum has separated before

operating. This requires about eleven months. To operate earlier is not advantageous because the limits of the destructive process can not be discovered. Abscess should be incised and drained.

OSTEOMYELITIS

Acute osteomyelitis should be treated in its earliest stage before the *x*-ray can throw any light on the diagnosis. The treatment demanded is operation. The disease consists in an infection of the medullary tissue; the products of inflammation can not be accommodated in the unresisting bone, and pressure necrosis rapidly takes place. The sooner the bone is trephined, and vent given to the pus, the less will be the destruction. Operation should be done as soon as the diagnosis is made. This is much more of an emergency condition than many other diseases which are so regarded. To treat an osteomyelitis of the tibia or femur with tentative measures, waiting as was once the practice until a sequestrum forms, is a grave surgical sin, as metastatic infections in other parts of the bone and in other organs are very apt to develop. Destruction of the shaft continues until the pus finds a vent; it is the surgeon's duty to provide this vent at once. Not only does every hour of delay endanger more bone, but the life of the patient is threatened by septicemia until free drainage is secured (Acute Osteomyelitis: J. P. Warbasse, Jour. Am. Med. Assoc., Apr. 17, 1915). The description of the operation will be found in the chapter on Operations on Bones and Joints. Here also is described the treatment of the subacute and chronic stages.

It sometimes occurs that a *chronic abscess* develops in bone without the formation of sequestrum. Such a cavity is treated the same as a cavity containing a sequestrum.

Typhoid osteitis should be treated the same as the other forms. Osteomyelitis should be met by trephining the bone as soon as the disease is recognized. The cavity should be sterilized with 5 per cent. phenol or 1 : 500 hypochlorite of calcium, and the wound closed without drainage in order to avoid infection with other organisms.

TUBERCULOSIS OF BONE

This disease is usually found in the epiphyses, although it may occur in any part of the bone. It is a disease of childhood; but it occurs also in adults. The treatment is first prophylactic. Healthy children, living under hygienic conditions are not prone to have the disease. The most important part of the treatment of the disease itself is hygiene. This is described under Tuberculosis (page 276). Heliotherapy (Vol. III) gives remarkably good results. Children with tuberculosis of bones and joints require fresh air day and night, light, and if possible life at the seashore. Uncomplicated tuberculous foci in bone may be exposed and curetted out. The common complicated tuberculous diseases, such as occur in the spine, hip and knee, are best treated by general hygiene and local immobilization. The treatment of these conditions is described under their various regions. The general treatment of the tuberculous individual should go hand in hand with the local treatment. Of the two the general treatment is the more important.

Tuberculosis in adults is a much more serious condition than in children. It yields less readily to general treatment, and, if extensive, is poorly amenable to local treatment. Complete removal of all of the diseased tissue is often called for; and in many cases amputation is the most conservative measure. In all serious cases a mixed and complicated infection is present, and must modify the treatment.

Uncomplicated tuberculous foci in bone are best treated by complete eradication of the disease. This is the principle which applies to all tuberculous lesions: if the disease can be removed by surgical measures without sacrifice of important structures, the operation should be done. One reason for this treatment is that by hygienic measures the surgeon never knows when tuberculosis is well as the spores of the organisms may remain encapsulated indefinitely—always ready to light up a new fire. Early diagnosis is, of course, essential for successful treatment. The bone should be exposed by a full incision. The joint should not be opened. A trephine, or chisel, or burr opens the bone. The opening should be large enough to curet out all of the disease. The removal of bone should extend well beyond the disease, even though it pass through the epiphyseal cartilage. The joint should not be invaded.

The cavity in the bone should be swabbed with tincture of iodin, and packed with iodized gauze. In a few days when granulations appear, the cavity may be filled with bone-filling paste (page 705).

Such operations may usually be done on the upper end of the tibia, lower end of fermur, upper end of femur, and the long bones near the elbow and ankle. The neck of the femur is reached by trephining the great trochanter.

SYPHILIS OF BONE

Syphilis of bone is treated the same as syphilis of other parts. The disease yields to antisyphilitic measures. Destructive process and distortions, after the subsidence of the inflammation, may be remedied by osteoplastic operations (see Syphilis, page 283).

TUMORS OF BONE

Fibroma, chondroma and **osteoma** are important because of mechanical interference with function or because of pain. If any of these conditions exist, or if the tumor is steadily growing, or is approaching an important structure, or if the possibility of easy removal is becoming less and less, then the tumor should be excised. These tumors will recur if not completely removed. In the operation, healthy bone which is essential for the strength of a limb should be left. These operations offer opportunity for plastic work, to fill the gap or restore the strength of the bone. Gaps often require to be filled or the continuity of a bone restored (see Bone Operations, page 688).

Sarcoma demands early and complete excision. The giant-celled medullary type and the slow-growing fibro-sarcoma require the least radical treatment. The common round-celled sarcoma requires wide extirpation. Usually this should involve the whole bone, amputation being done at the joint above. This is advised because of the great danger of recurrence, and because of the tendency of metastases to be deposited in the bone itself.

Conservative operations for malignant tumors are described elsewhere (see Operations on Bones, page 688).

Carcinoma of bone is always secondary, either by metastasis or extension. Complete excision of the disease is required; but often this is not indicated because of the existence of ineradicable disease in other parts. Fractures occurring as a cause of malignant disease may call for amputation. Resection of the disease may sometimes be done.

Cystoma of bone may be of various characters. That due to broken down sarcoma requires the same treatment as that given for the original disease, unless, as has sometimes occurred, the original tumor structure has entirely broken down and disappeared. Echinococcus cysts should be opened freely, every bit of liningstructure destroyed, and the cavity drained. Osteoplastic obliteration of bone cavities often becomes necessary (see Operations on Bones).

CONGENITAL DEFECTS OF BONE

Defects in the development of bone result in deformities which may be remedied by surgical means. Most of these conditions are described under their respective regions. Curves in bones are corrected by splints, by osteotomy or osteoclasis. Overgrowth in the length of one of two parallel bones may be corrected by resection of a segment of one bone or by an osteoplastic lengthening of the other. The latter operation is done by producing a step-shaped osteotomy (see Operations on Bones).

OSTEOGENESIS IMPERFECTA

The important thing is to recognize the disease early. These children are often born with fractures which occurred *in utero*. When during delivery such fractures are discovered or new ones occur as the result of slight force the disease should be thought of, and the greatest gentleness of handling employed. Most of these children soon die; but the treatment should consist in the minimum of handling and the maximum of nourishment, and good hygiene with the hope that the disease may be overcome.

ACHONDROPLASIA

This is a congenital disease in which the legs and arms are short and the long bones soft and easily distorted. The treatment consists in good hygiene and nourishment. Later in life, deformities may be corrected by operation on the bones.

FRAGILITAS OSSIUM

This condition is really a symptom of several different pathologic conditions. A diagnosis of the cause of the fragility should first be made and the condition treated. Spontaneous fractures require the same treatment as fractures due to violence.

LEONTIASIS OSSIUM

The cause of hypertrophy of the bones of the skull is not known, and no preventive or specific treatment can be applied. The treatment of disease of the pituitary body may prevent it. When the hypertrophy is localized, the bone may be chiseled away. This has been successfully done, and no recurrence noted.

OSTEOMALACIA

Good hygiene seems to be of value—fresh air, nourishment and baths. As excessive ovarian secretion seems to be associated with this disease, just as excessive thyroid secretion is associated with exophthalmic goitre, resection of ovarian tissue is the natural surgical treatment. As the disease is aggravated by childbirth, women patients should not become pregnant. Removals of the ovaries and testicles have given good results in some cases, just as the climacteric has marked the beginning of improvement in others. There is some peculiar relation between this disease and hyperthyroidism, because the serum of thyroidectomized sheep has been of benefit in the treatment. Treatment with adrenalin has also brought about some striking cures, and in other cases, for some unknown reason, has had no beneficial effect. It is probably of value, because it has been shown that sheep, from which one suprarenal gland has been removed, suffer from osteoporosity. **Senile osteomalacia** yields to treatment with phosphorus and cod-liver oil.

OSTEITIS DEFORMANS

This disease is usually observed in the poorly nourished or syphilitic. The treatment consists in improving the hygiene and in general nourishment. Where nerve pressure from the deformed bone causes pain, relief may be sought by operative removal of the pressure, counterirritation, or massage.

FRACTURES

General Considerations.—The two first important requisites in the treatment of fracture are that (1) the surgeon should have an accurate mental picture of the condition with which he has to deal, and that (2) he should have a clear understanding of the pathological processes associated with fracture. Knowledge of diagnostics and pathology are at the foundation of successful treatment; and a mechanical sense is a prerequisite of the next greatest importance. *Art first, and force only with art,* should be the surgeon's motto.

In the treatment of a fracture the surgeon should bear in mind that he is dealing with a wound, a lacerated wound of bone, which in its pathology and treatment is amenable to the same laws which govern wounds in other tissues. A fracture is necessarily associated with rupture and injury of blood and lymphatic channels, not only in the bone itself but also in the periosteum and surrounding soft tissues. In the case of fractures of long bones this injury to the vessels of the soft tissues is very considerable. Blood and lymph escape from the torn vessels, and exudation of serum and leukocytes takes place through their walls. This exudation occurs from vessels (1) which have been directly injured by the fracturing force, (2) which have been irritated by fragments of bone, (3) which have been injured by stretching or distortion, (4) which have been irritated by the fluid poured out of the injured vessels, or (5) which have become dilated through local vasomotor paralysis from injury to their nerves. From these damaged vessels there at once begins an exudation of serum and blood cells; and the surrounding tissues become infiltrated with the products of this traumatic inflammation. The conditions here are comparable to those of a wound of the soft parts; and here, too, will the healing be influenced by the absence or presence of infection, by the niceness of the reposition of the wound surfaces, by the perfection of the immobilization of the wound, and by the nutrition of the parts.

This exudate undergoes the changes of wound exudate. The fluid is absorbed, and the new round connective-tissue cells become converted into spindle cells, which form a network with the fibrin. The exudation involves, in a greater or lesser degree, the surrounding muscles, nerves and vessel walls. Immediately about the bone ends the exudate is so prolific that when its fluid has been absorbed, and the new connective tissue has contracted, it forms a firm mass of scar tissue (callus), which becomes infiltrated with osteoblasts and converted into bone.

These conditions require to be treated the same as in any other wound. In simple fractures the asepsis of the wound is already secured. We have, therefore, to look to the next important steps in wound treatment—coaptation, immobilization, and protection. That means, in the parlance of fractures, correction of displacement, fixation, and protection from mechanical disturbances. The surgeon has to consider in this treatment not only the wound of the bone but also the lesions of the soft tissues.

The **immediate treatment** of fractures is based upon two fundamental principles—the correction of the deformity and the holding of the fragments in normal apposition until they grow together. The methods of replacing the fragments in their natural positions varies much with the character and location of the fracture. In many fractures there is no displacement of the

fragments. In others the displacement may be very great. Simple fractures without displacement are sometimes changed into fractures with displacement or into compound fractures by movements of the limb immediately after the accident. It is not uncommon for a simple fracture to be rendered compound by penetration of the skin by a sharp point of bone. It is, therefore, important that care be exercised to prevent these injuries from being made worse.

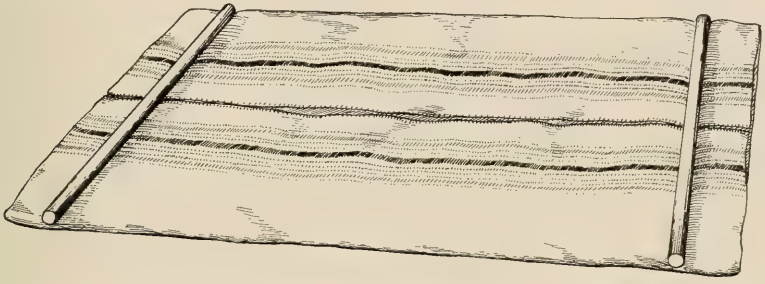


FIG. 315*a*.—BLANKET AND STICKS FOR CONSTRUCTION OF EMERGENCY SPLINT. The ends of the blanket are to be rolled around the sticks.

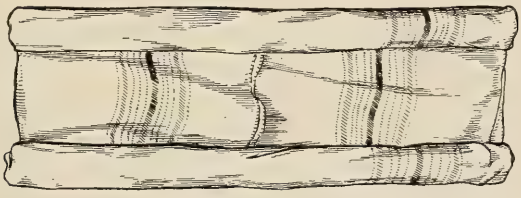


FIG. 316.—EMERGENCY SPLINT MADE FROM STICKS AND BLANKET FOR TREATMENT OF FRACTURES OF LEG.

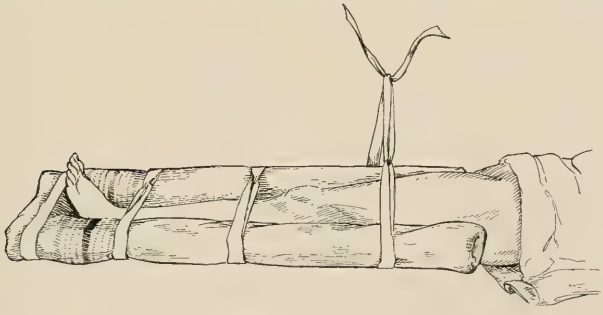


FIG. 317.—APPLICATION OF EMERGENCY BLANKET SPLINT TO LEG.[1]

A fractured limb should be kept as still as possible until the fracture region can be exposed. Trouser-legs, drawers, shoes and stockings should be cut off if their removal otherwise can not be accomplished without undue moving of the injured limb.

The clothing should be removed with such care as not to inflict avoidable pain upon the patient or injury to the fracture. This should be done systematically. Clothing from the upper part of the body should be removed first. Coat and vest may be slipped off with the assistance of some one to hold the patient in a sitting position. Shirts may be removed if necessary by cutting the sleeves or bisecting the garment in the middle in front or behind. Women's waists may be removed by cutting the sleeves. Trousers, draw-

ers, and skirts may be removed by having an assistant lift the pelvis; or they may be cut off. If possible garments should be saved by cutting the stitching at the seams rather than cutting the substance of the fabric. The preliminary examination should simply be for the purpose of making a diagnosis of the existence of fracture and correcting dangerous deformity. Then the patient should preferably have the fracture temporarily immobilized and taken to the most convenient place for further treatment (see First Aid to Injured, Vol. III).

For example, in the case of a complete fracture of the bones of the leg or thigh, when the limb is moved, it should be supported both above and below the seat of fracture, being grasped in such a way as to prevent rotation as well as angular motion. When the patient is to be moved from the place of the accident, motion of the fragments may be prevented by putting on *extemporized splints* (Figs. 316 and 317) of board, straw, rolls of paper, blanket, cloth, twigs; or an injured leg may be bandaged to its fellow with a pillow between. The patient should be carried, if possible, in the recumbent position, upon a litter. The subsequent treatment of fractures of the lower extremities should be conducted upon a hard bed. The bed should be so firm as not to sag with the weight of the body. This can be accomplished by placing boards (a "fracture board") between the spring and the mattress. The patient should be undressed, washed and made comfortable. A limb which is to be manipulated should not be dirty.

In the *correction of the deformity*, or the setting of the fracture, the correcting force should be applied gently, firmly and gradually increasing until the desired result is secured; not quickly and abruptly. When there is simple lateral displacement, the limb should be grasped firmly by one hand above and by the other hand below the fracture, and, as steadily increasing traction is applied, the lower fragment should be slipped over into place. The same method of applying extension should be pursued in correcting fractures with overriding and with rotary displacement. When the muscular resistance to correction is still greater, an assistant may make counterextension above and steady the leg while the surgeon with both hands applies traction and correcting manipulations. In correcting angular displacement, whether the fracture be complete or of the green-stick variety, extension should be employed at the same time with the lateral force which overcomes the angulation. The deformity of impacted fracture is overcome by direct traction applied to draw apart the fragments.

While the expedients for facilitating diagnosis are not a part of this book a plea for more accurate diagnosis is urged. The surgeon should have before his eye a picture of the bony wound. This is the first step in the treatment. It will contribute much to his peace of mind to have a positive conception of just what he is treating. Time and pains in making a satisfactory diagnosis are well spent. The value of comparison of the injured limb with the sound limb cannot be emphasized too strongly.

Gentleness with firmness, and tenderness, that will be satisfied with nothing short of normal apposition, are the qualities that make for the best results. It is always on the side of wisdom to have an assistant. This is particularly the case in putting up fractures of the lower extremity, in which the assistant can make counterextension and render assistance in supporting the limb.

General anesthesia is of aid in diagnosis and in the reduction of deformity by overcoming the two obstacles: muscular contraction and pain. Judgment is required in determining of the advisability of its employment. I have seen it neglected when it was eminently indicated; and used when it could add

nothing further to the diagnosis, when not at all called for in the treatment, and when it did nothing but add to the general confusion and exaggerate the importance of the injury. Local anesthesia may be used just as effectively in cases properly selected. The nerve trunks may be anesthetized or diffuse infiltration of the fracture region may be practised.

Obstacles to Reduction.—Ordinarily the reduction of a fracture is simple and satisfactory, but there are certain *obstacles to reduction* which may intervene. The muscular contraction may be so strong that it resists the combined efforts of both surgeon and assistant. A second obstacle is great pain. A general anesthetic overcomes both of these. If it is used, the splint material should be at hand to apply while the patient is still relaxed. Tenotomy and the subcutaneous division of muscle are sometimes necessary, especially when muscle and nerve are irritated by displaced fragment of bone or other irritating material. Normally the muscles lying along the bone are long enough to permit of the reduction of any fracture. It is irritation which causes them to contract, and prevents reduction. When the fracture has been perfectly reduced this irritation is overcome, so far as the bone fragments go, but is continued by the presence of the blood and exudate, and is necessarily present in a greater or lesser degree. There are many expedients for rendering the muscles less irritable. Among these may be mentioned the administration of sedative drugs. Compression of the artery supplying the limb will often cause the muscles to relax. Producing anemia by the ischemic rubber bandage may be employed. The injection or the infiltration with novocain or cocain of the nerve trunk supplying the contracted muscles is often of value. Stimson's method of tiring out contracted muscles by making continuous extension against them can not be recommended. Immediate and complete reduction is the thing. To apply continuous extension to the fragments of the femur, with the expectation that in a few hours the muscular resistance will be overcome, is usually encouraging a false hope. The surgeon should not rest until the reduction is effected. Experience has impressed me that if a given weight does not correct the deformity in a few minutes, it never will. Every minute's delay with the displacement uncorrected is adding to the infiltration of the muscles and decreasing their elasticity.

An important obstacle to reduction, which is often mistaken for muscular resistance, is the interposition between the bone fragments of muscle, clot, periosteal tissue, fascia, or loose fragments of bone. I have seen 40 pounds of extension applied to a fractured femur, and the overriding and displacement not perceptibly influenced, because of the interposition of a bundle of muscular tissue between the fragments. When a satisfactory reduction cannot be effected because of these things, the best surgery demands the operative exposure of the fracture and the removal of the hindrance to reduction. It may be borne in mind, however, that if no infection is present, none of these obstacles, although they will retard it, will actually prevent the osseous union of the fragments; for they are all capable of being incorporated in the callus, and infiltrated with bone tissue. One of their objections is that they render immobilization more difficult, and thus conduce to non-bony union.

Immediate Reduction.—The following proposition cannot be too strongly emphasized: *The reduction and immobilization of fractures should be attempted as soon as possible after the accident.* Delay increases the infiltration of the surrounding tissues and adds to the spasticity of the muscles and other soft structures. Time should not be wasted with lotions and fomentations. If a fracture with overlapping has been allowed to go uncorrected, the infil-

tration with exudate of the surrounding tissues so rapidly destroys their elasticity that reduction without operation may soon become impossible, nor may the surgeon expect to overcome the resistance by general anesthesia. Finally, the more motion and distortion that take place before final immobilization is applied, the greater will be these difficulties. Here is a plea for the gentle handling of fractures.

Artificial leverage in the reduction of fractures was developed by H. Gifford (Surg. Gyn. and Obst., Feb., 1916). The heavy iron clamp, such as is used by joiners and cabinet makers, is employed in connection with blocks and strips of wood to give pressure at the desired points. The simple mechanical principles of pressure and counterpressure are invoked. The blocks must be well padded. It is possible in unskilled, or too strong, hands for this method to do much harm. It is applicable to a few selected cases in which the surgeon is sure reduction is not hindered by the interposition of soft tissues. It may be applied to the long bones of the extremities and has been successfully used in the lower end of the radius, and in the humerus, tibia and fibula.

The condition of the skin should be looked to before proceeding further with the treatment of a fracture. Serous blebs should be snipped with scissors at their most dependent part, and their fluid evacuated. The overlying skin need not be removed, but should be covered with a bland antiseptic powder on a few flat layers of dry gauze. Excoriations should be covered in the same way.

When a limb can be washed without disturbing the fracture the skin should be cleansed with soap and water. This operation cannot be recommended in all fractures because of the mobility between the fragments which it entails. However, in cases of fracture of one of two parallel bones, or in cases of limbs where the skin is particularly unclean, or in the presence of threatening perforation of the skin, it is indicated. Chemical disinfection is easier. The surface should be examined for prominent points of bone which might penetrate and render the fracture compound. If such a point is discovered, further manipulation should be resorted to with the view of securing a more perfect reduction. This condition is not infrequently observed in fractures of bone covered only by skin, such as the anterior border of the tibia. When a perfectly satisfactory result cannot be effected, the danger of penetration of the skin may be lessened by applying a compressing pad of gauze. Care should be taken that the compression is not made on the threatening point, but above or below, against the bone with which it is connected. No encircling band or bandage should be applied next to the skin beneath a splint unless the rest of the limb beyond is completely covered by bandage equally firm, and the ends of the fingers or toes left exposed to view.

The **immobilization of the fragments** is accomplished by one of the following means: by position, by splints, by bandaging, by extension, or by direct fixation. In certain cases the fracture remains in correct position without the use of any of these artificial means. The placing of the parts in a certain position—as, for example, the use of the double inclined plane in fractures above the knee, or the dorsal recumbent position of the body in fractures of the clavicle—often suffices to retain the bones in the desired apposition. After the fragments have been put in position and a permanent splint applied there should be little or no pain. A splint should give to the patient a feeling of comfort and support to the part.

If there is persistent pain he should not be encouraged to believe that it will subside, but the surgeon should know that there is something wrong, and the cause of the pain should be sought. An uncomfortable splint

should not be left on. Usually, if the pain is not due to the splint, it will be found that the injury of the bone and soft tissues is responsible. Pressure upon a nerve by a fragment of bone is a common cause of persistent pain. If this cannot be corrected by manipulation to effect better reposition, it should be exposed by operation.

The materials used for splints are plaster-of-Paris, silicate of soda and potash, chalk, cement, glue, papièr-maché, leather, felt, metals such as aluminium and tin, wooden boards, paper boards, and other stiff substances (see Materials, page 55). The most satisfactory splints are those which can be moulded to conform to the shape of the part to which they are applied. Splints of thin metal come ready made in various shapes to fit different parts. These are serviceable, and are applied with gauze padding, being held in place with muslin bandages and secured from slipping by adhesive plaster. Woven wire splints, and splints of wire rods are also used. Wooden splints are made of basswood. Basswood splints are flexible and very useful. They are made in pieces 3 or 4 mm. (⅛ inch) thick, 40 cm. (16 inches) long, and 9 cm. (3½ inches) wide. One or several may be used. They are of especial value for incorporation in plaster-of-Paris splints to give stiffness with less plaster. Thicker non-flexible boards are also used. Padding of gauze should be placed between the splint and the skin. The old-fashioned fracture-box occasionally is of service. It is an oblong box, forming a trough, into which the leg may lie supported upon padding or sand. A useful splint, called the "rolled splint," is made of strips of wood, 7 mm. (¼ inch) wide, 3.5 mm. (⅛ inch) thick, 30 cm. (12 inches) long, laid closely together upon a strip of adhesive plaster 7.5 cm. (3 inches) wide. Such a splint has great capacity for conformity (see Fractures of Humerus, page 562).

Plaster-of-Paris is the most valuable of the materials used for splints. In most cases it is best employed in the form of the plaster bandage. In using plaster-of-Paris, the dressing of a fracture of a lower extremity should never be attempted on a soft bed. The best bed for this purpose is one that is narrow and having a thin mattress resting on boards instead of springs. Or better still, the leg should lie upon a table or chairs, until the plaster has hardened. The patient should lie recumbent and relaxed, and not watch the operation. There is a very prevalent notion that a plaster cast should not be applied to a fractured limb until the subsidence of the traumatic swelling. As a matter of fact this swelling is largely due to imperfect immobilization and will stop as soon as the limb is properly encased in a plaster dressing. The skillful surgeon need have no hesitancy in applying a plaster bandage to a fracture of both bones of the leg immediately after the accident and before any swelling has developed. If the fracture of the tibia is an oblique one there will be overriding. This is overcome by the assistant who makes traction, while another assistant stands opposite, supports the leg, and rubs smooth the bandage. The foot, at a right angle, and the bony prominences of the knee furnish the two points of purchase which hold the leg in traction against the muscles after the plaster has hardened. By the time the last bandage is applied the cast should be firm enough to support the leg. This is the ideal dressing for this fracture.

If the person applying a plaster dressing is skilled in its use no covering for the leg is necessary. The skin may be shaved, covered with vaselin, and the plaster bandage applied directly to the skin. If a covering for the leg is desired, the best is a seamless white cotton stocking; for the arm, the sleeve of a cotton undershirt; or for either, the elastic tubular jersey sleeving. If the bandage is to be put on by a novice or if there is much contusion and dan-

ger of swelling, a thin layer of cotton should be applied to the leg before the plaster is put on. Cotton wool should not lie next to the skin.

The poorest plaster bandages to which we have access are the bandages of the shops. These are made of crinoline, which are rich in stiffening made of starch or glue. The best bandages are those which the surgeon can make himself. The materials for these bandages should be crinoline which has been washed to remove the stiffening, dried and cut into desired widths and lengths. Into the meshes of this is rubbed dehydrated, dental plaster-of-Paris, and the bandage loosely rolled.

Before using, the bandage should be covered with three or four layers of ordinary crepe paper, to prevent loss of plaster. Thus wrapped, the bandage is placed on end in the water which should be sufficiently deep to cover it. To hasten hardening, the water should be as warm as the hand can stand and may have added to it three or four teaspoonfuls of sodium chloride to the liter (1 quart) of water. After a few minutes, when bubbles cease to come up from the bandage and water has saturated it, it is carefully removed from the water in such a way as to lose as little plaster as possible, the two ends being covered with the hands and the excess of water gently squeezed out. The roll is then straightened out, the paper removed, the loose raveling of warp threads at the ends pulled out, and the bandage handed to the surgeon for application.

In applying a plaster casing to a broken leg, for example, the desired position having been secured, the leg is held by an assistant or is supported on apparatus. In this operation the foot of the stocking, the tricot tubing or bandage may be allowed to extend beyond the toes to give a hold for the hand. A strong and dependable assistant is necessary for the important duty of holding the leg. One hand should support the leg just above or at the fracture, the other should hold the foot at a right angle. If there is an oblique fracture with a tendency to overriding, one assistant is needed to make traction and another to support the leg with a hand on either side of the fracture (Fig. 318). If traction is not necessary the foot may be supported by grasping the toe of the stocking or the part of the bandage extending beyond the toes. To facilitate holding the foot the toe of the stocking may be grasped by a heavy pedicle clamp (for methods of applying traction, see page 487).

The leg being held, a 10 cm. (4 inch) bandage is applied at the region of the fracture and extending above and below for a distance of 25 or 30 cm. (10 or 12 inches). When one bandage is taken out of the water the next bandage is put in. A second wide bandage is applied from the ankle to the knee, and a third and fourth running above the knee. Then a narrower bandage is begun at the roots of the toes and made to cover the foot and ankle. By applying some long spiral turns or a few longitudinal strips, and by rubbing well together the layers as they are applied, the firmness of the splint is much increased and the amount of material required diminished. The most important feature in the application of a plaster case, next to securing the desired position, is that the inner layers of the bandage shall lie smoothly and that the pressure made by the bandages be perfectly even. Bandages should lie flat and not be applied with one edge making more pressure than the other. No surgeon is competent to apply a plaster case who does not appreciate the importance of this thesis; and he is much more competent if he has taken occasion to make examinations of the inside of plaster cases after they have been removed. The splint may be strengthened by incorporating between its layers strips of wood shaving, wooden splint material, strips of wire gauze or thin metal. While it is impossible to lay down rules, most plaster

cases applied outside of hospitals are from 2 to 4 times as thick as is necessary.

FIG. 318.—APPLICATION OF PLASTER-OF-PARIS TO LEG FOR FRACTURE WITH OVERRIDING. One assistant makes traction and keeps the foot in proper position, the other supports the leg and maintains proper alinement, while the surgeon applies the bandage.

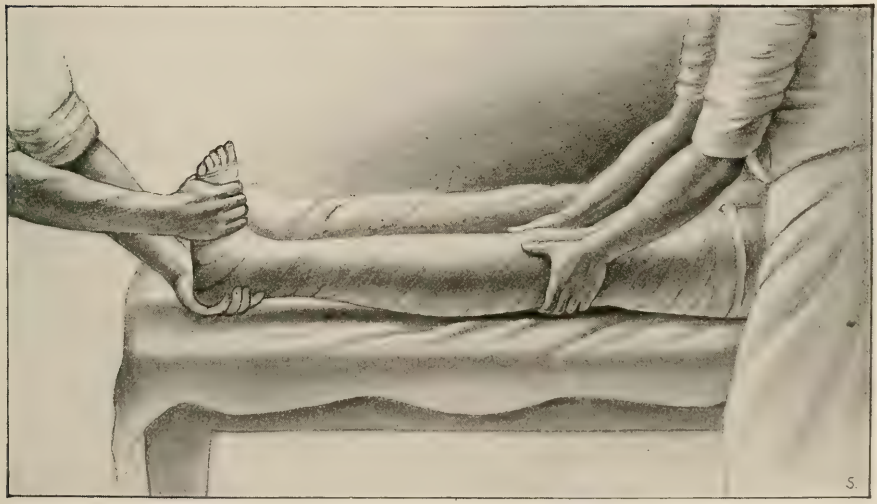


FIG. 319.—MAKING TRACTION BY HAND WHILE A PLASTER SPLINT IS DRYING.

After the bandage has been completed traction should be continued until the splint is hard enough to hold the desired position. This traction may be applied by the hands (Fig. 319) or by a loop of bandage around the ankle.

Instead of applying the bandage first to the region of the fracture, some surgeons prefer to apply it first below the fracture beginning 2 or 3 cm. (1 inch) below the break and extending as low as desired. This case to the lower fragment is allowed to harden. Then a similar plaster case is applied to the upper fragment, beginning 2 or 3 cm. above the fracture and extending as high as desired. This section of the splint is allowed to harden. Then traction is made on the lower part and counterextension on the upper part, the limb is adjusted to the desired position, and a plaster bandage applied over the intervening part of the limb, and embracing the adjacent parts of the splint above and below. Thus the splint is completed, while the two fragments are under the best control. This method has much to recommend it, and is to be advised especially where traction is needed to overcome overriding.

FIG. 320.—RESULT AFTER APPLICATION OF PLASTER-OF-PARIS CASE FOR FRACTURE OF LEG.

Drawn from case applied by author.

In applying the undermost bandages it is important that they should be allowed to run in the direction in which they will lie flatly. Reverses and turns should not be made. If it is desired to change the direction of the bandage, it should be cut in two and started running in the new direction. It is my practice to have an assistant or nurse stand by with scissors, and bandages are constantly cut in preference to negotiating a change of direction. For esthetic purposes the outer bandage should be 6 or 8 cm. ($2\frac{1}{2}$ or 3 inches) wide, and have a selvage edge. This is applied with the decussations running up the dorsum of the foot and front of the leg (Fig. 320).

In applying a plaster bandage to a fracture of the leg, if the surgeon has the help of one assistant; it is better that the more experienced of the two should hold the leg and the less experienced should apply the plaster, because the former is the more important function.

In order to diminish the amount of plaster adhering to the hands they may be anointed with vaselin. Better than this is the wearing of rubber gloves or covering the hands with rubber tissue. Plaster can be washed from the hands by scrubbing them with sugar and water. In applying plaster the surgeon should not bespatter the neighborhood, for it is possible to perform this operation without drop-

ping a speck of plaster. In applying plaster to other parts the same general principles apply as in the above illustrative application to the lower extremity.

Fenestra are cut in plaster cases to expose wounds for subsequent dressings. The best time to cut a window is immediately while the plaster is still soft. Immediate fenestration is done as follows:—The wound, after proper treatment is covered with a square of dry gauze made up of four or five thicknesses and extending 1 or 2 cm. ($\frac{1}{2}$ or $\frac{3}{4}$ inch) beyond the limits of the wound. The skin around the dressing is thoroughly covered with zinc oxide powder. Over this is laid a square of rubber tissue, oiled silk or oiled muslin, extending 5 or 8 cm. (2 or 3 inches) or more beyond the wound in all four directions. The plaster-of-Paris case is then applied. When the case is finished a square or oblong is marked out, the lines of which fall between the outer edges of the gauze dressing and the rubber tissue. This is done according to memory or measurements; or the form of the gauze pad may be seen through the

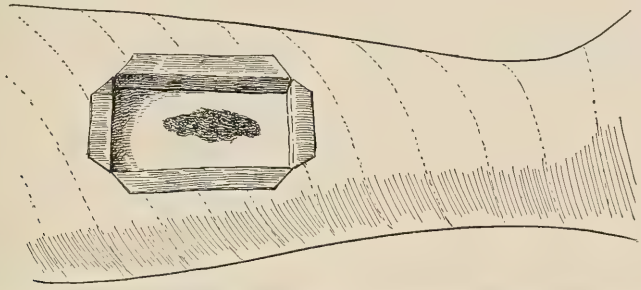


FIG. 321.—PLASTER-OF-PARIS SPLINT WITH WINDOW FOR DRESSING WOUND.
Note rubber tissue reflected over edges of opening.

plaster. For cutting the window the best instrument is a sharp scalpel. This operation is quite as important as some operations for dividing the tissues and a good knife is as essential. If the plaster is of good quality, and has been well put on, it will cut like cheese. The fabrics covering the rubber tissue are cut through after the fenestrum is completed. The rubber tissue is then divided by lines running from the center out to the four corners, the apices of these four triangles are cut off, and the remainder reflected over the cut edges of the plaster (Fig. 321). More zinc powder is used, and a suitable dressing is then applied to the wound.

In place of the rubber tissue the edges of the window may be covered with paraffin, shellac or water-glass. If more than one fenestrum is required or if the fenestrum involves more than half of the circumference of the cast, the latter should be strengthened by incorporating some strengthening strips as described above. Or a strip of metal should be made to bow over the opening. By using two such supplementary braces the whole circumference of the cast may be cut away (Fig. 322). For this latter purpose wire mesh or cardboard, strengthened by plaster bandages also is useful.

For purposes of inspection, a plaster splint may be cut down on either side of the leg while still soft. After the hardening is complete the cutting may be finished and the front half lifted off and replaced at pleasure. This *bisected case* is very useful (Fig. 323). The two halves may be bandaged together.

For cutting dry plaster dressings, many tools have been contrived but none is perfectly satisfactory. A carpenter's mitre saw answers fairly well.

If a smooth edge is not desired the plaster may be softened where it is to be cut by painting a line with vinegar or acetic acid and cutting with a sharp strong knife. The difficulties of cutting dry plaster are obviated by doing the cutting while it is soft, and if necessary holding the two halves together by a bandage. In applying a plaster splint to the leg, I have practised

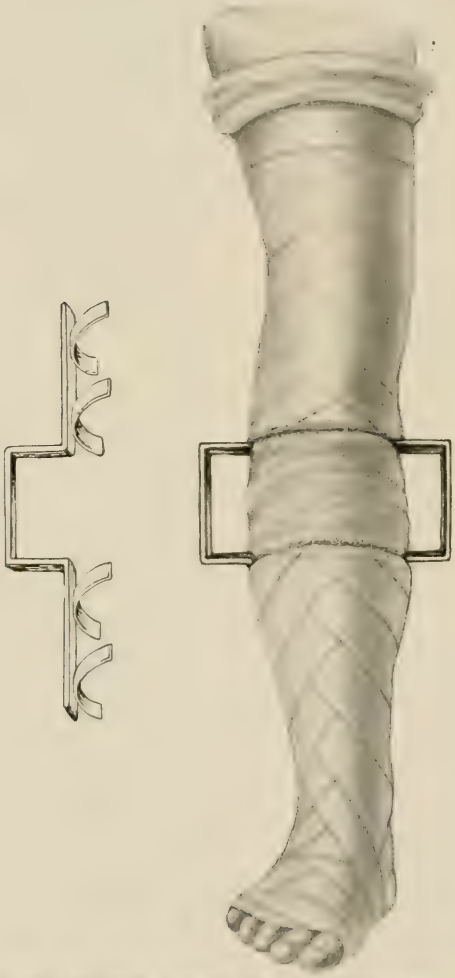


FIG. 322.—METHOD OF APPLYING SPLINT TO FRACTURE ASSOCIATED WITH A LARGE WOUND.

Two iron braces pass across the fracture and make possible the cutting of a large window for dressing the wound.

putting on one less bandage than necessary and bisecting the plaster case while it is still soft. A final plaster bandage is then applied. If the line of junction does not show plainly through this last bandage it may be marked with a blunt instrument. This case can be cut off easily with a sharp knife at any time or be temporarily removed without damage to the splint as only the outer bandage remains to be divided. The edges of a bisected cast may be bound with strips of adhesive plaster. To make such a splint fit more

snugly to the atrophied leg it is often desirable to cut out a narrow strip of plaster from the case on either side.

Gutter splints of plaster-of-Paris are most satisfactory additions to the plaster splint technic. They are made by laying out on a table moist layers

FIG. 323.—BISECTED CASE.
Showing plaster-of-Paris splint divided into anterior and posterior halves for exposure of limb. Drawn from photograph of splint applied by author

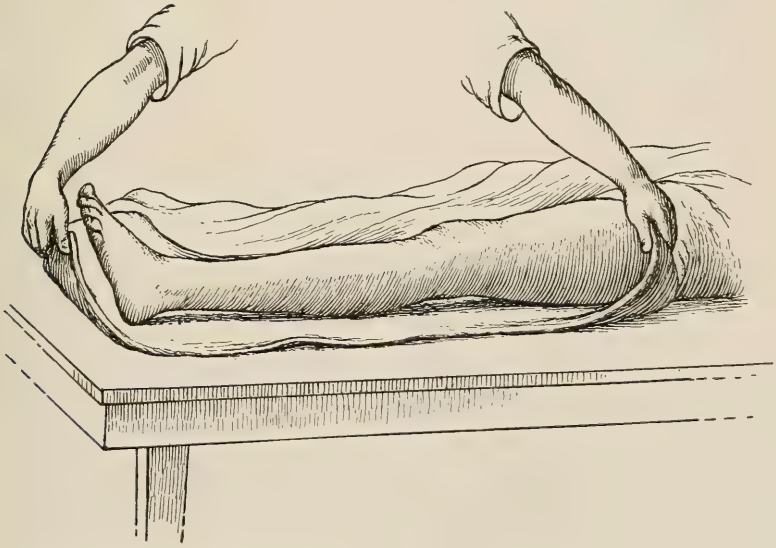


FIG. 324.—PLASTER-OF-PARIS GUTTER SPLINT READY FOR APPLICATION.
The moist pliable splint is placed under the limb and made to conform to the leg and foot.

of wide plaster bandage, run back and forth to make a splint of the desired length and eight or more layers thick. Or the proper width of crinoline or muslin may be laid out and the cream of plaster rubbed in it. It should be wide enough to envelop about three-fourths of the limb (Fig. 324). These layers should be well rubbed together. This splint is then picked up, placed

under the limb to be immobilized, pressed about it to take the desired shape, and held on with a bandage of plaster or other material (Fig. 325).

Two narrower gutter splints may often be used to advantage, one anteriorly and the other posteriorly, the two being held by a plaster bandage over

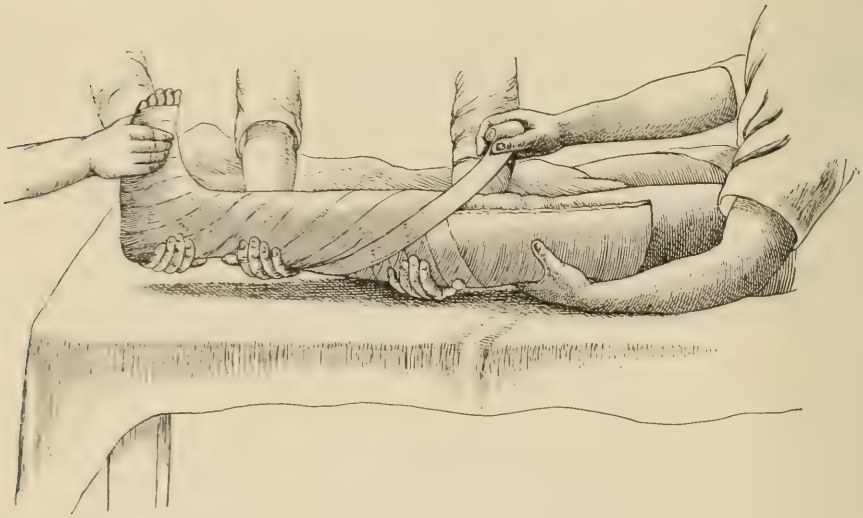


FIG. 325.—FIXING GUTTER SPLINT TO LIMB BY APPLICATION OF BANDAGE

One assistant supports the foot and makes traction, another supports the limb at the fracture and maintains alinement, while the surgeon applies the bandage.

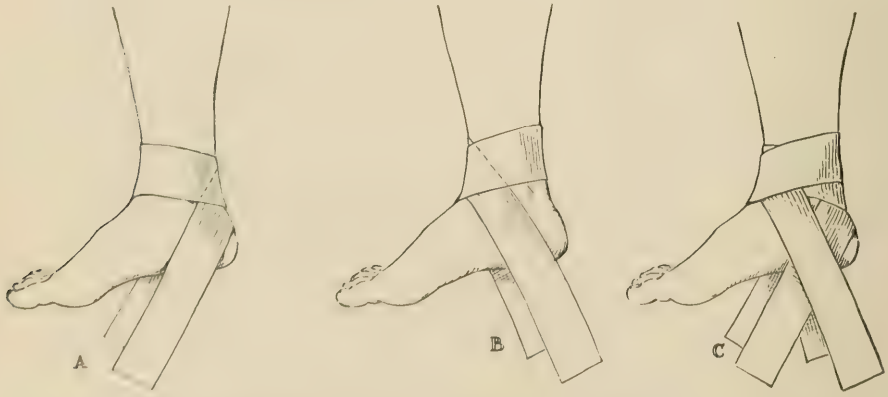


FIG. 326.—TEMPORARY LOOPS OF BANDAGE FOR TEMPORARY TRACTION.

Two loops of bandage are here represented. The ends should be caught together. *A*, Anterior loop; *B*, posterior loop; *C*, anterior and posterior loops combined.

all. Such a splint is easily divided laterally into halves. It is strong and more easily applied than the plaster case. To make the gutter conform smoothly and not wrinkle, it may be cut into laterally wherever necessary.

Such strips as this, made of several layers of smoothed-out bandage, are useful to strengthen other splints and lend themselves for the immobilization of many varieties of fracture. They may be used at the elbow, knee, shoulder and ankle as well as on the leg.

Other materials for making splints have been described (see Materials, page 57). These are used in the same manner and are amenable to the same rules as plaster-of-Paris.

For a lighter dressing of especial value are crinoline or the ordinary gauze bandage, impregnated with *silicate of soda* or stiffened with *starch paste*. Or the silicate of soda may be used in solution in the form of water-glass. Either of these materials lend themselves to the making of bandages, and are too little known and employed.

Temporary Traction.—For temporary traction, instead of depending upon the grip of the hands, it is often convenient to attach apparatus to the leg or forearm. A strong flannel bandage may be used for this purpose. It is best thrown about in two loops and the ends caught together on either side. Instead of two strips, four may be used and the two from either side

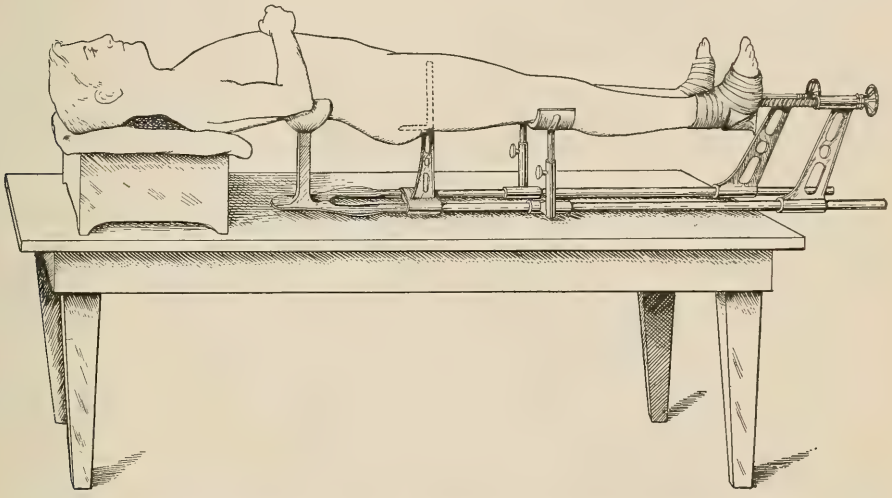


FIG. 327.—TRACTION APPARATUS FOR TEMPORARY TRACTION DURING CORRECTION OR DRESSING OF FRACTURES.

caught together below the sole of the foot (Fig. 326). The strips may be connected with a weight at the foot of the operating table or bed to make traction.

It is possible to apply a sliding removable tractor. This bandage should lie smoothly and be made of material which will slide upon itself when the traction is relieved. For this purpose silk is good or flannel smeared with vaselin. The ends of these traction loops should extend well beyond the sole. They should be tied together and separated 10 or 13 cm. (4 or 5 inches) by a block used as a spreader. A fracture-support for substituting untiring accuracy for the hands of an assistant is useful.

Mechanical support may be in the form of suspension. By throwing bandage supports about a limb and connecting them to a crane or rod above the bed the limb may be suspended. The best fracture frame is that devised by G. W. Hawley (Surg., Gyn. and Obs., March, 1918).

Apparatus is made especially for the purpose of facilitating traction. The Mueller-Lemon traction apparatus has much to recommend it. A modification of this mechanism should have a flange on the rest of the pelvic support so that pressure is made on the tuberosities of the ischium rather than on the perineum and pubic arch. A clamp should also be provided for

grasping the head of the tibia so that traction may be wholly confined to the leg when desired (Fig. 327). Fractures of the femur and leg bones may be drawn into position by this apparatus while plaster-of-Paris is applied or operations performed.

The method devised by Codivilla (Zeitschr. f. Orth. Chir., Bd. xii, 1903) consisted in driving a steel peg through the os calcis and using this as a hold for traction by means of a powerful screw apparatus. Counterpressure is

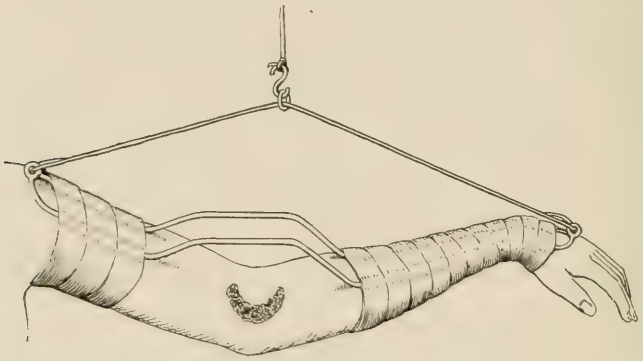


FIG. 328.—FRAME SUSPENSION SPLINT, ARRANGED FOR TREATMENT OF COMPOUND FRACTURE WITH LACERATED WOUND.

A bandage and gauze padding should intervene between the splint and the skin.

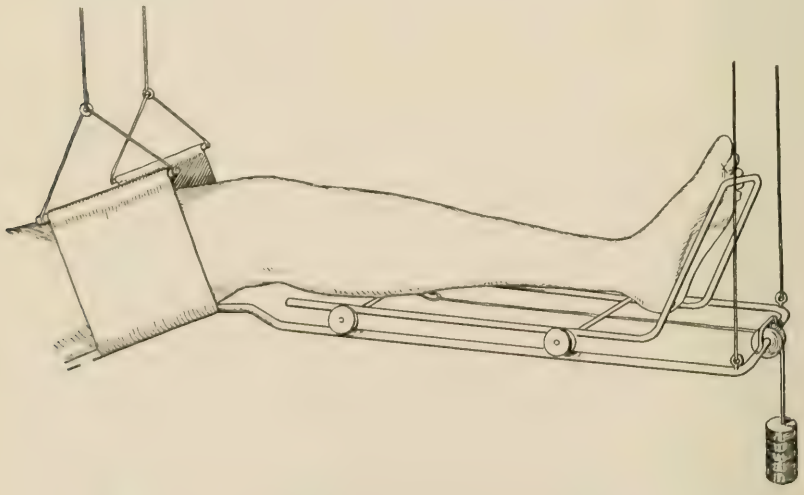


FIG. 329.—FRAME SUSPENSION SPLINT ADAPTED FOR TRACTION.

Abundant padding under the leg is required.

made by a post which impinges against the crotch. Traction is maintained by steel rods or plaster-of-Paris or the two combined after the screw traction is removed. This is rarely a justifiable procedure, because the peg can usually be driven through the lower fragment of the fractured bone without doing violence to the simplest mechanical and physiological principles. A sling around the ankle may be used in most cases in which a peg through the os calcis would seem indicated.

Wire frame suspension splints are particularly valuable for the treatment of compound fractures (Fig. 328) but serve well in simple fractures. The limb may be bandaged to the splint and suspended by cords and pulleys (Fig. 329). Traction may be added. The traction may be made in any direction. The special fracture frame-bed, having overhead apparatus for suspension, is desirable in connection with these splints (Fig. 330). By applying vertical adhesive extension to the foot the leg may be supported without any posterior rest or bandage contact (Fig. 331). The bandages

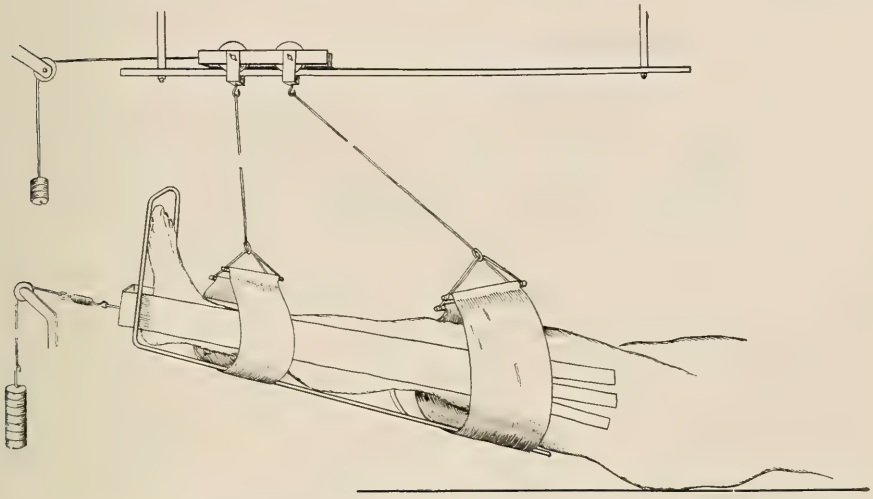


FIG. 330.—FRAME SUSPENSION SPLINT ADAPTED TO TRACTION FOR FRACTURE OF THIGH.

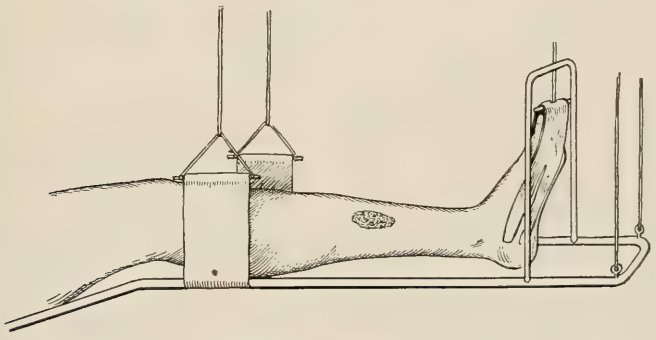


FIG. 331.—FRAME SUSPENSION SPLINT AS APPLIED TO LEG.

may be applied in such a manner that any part of the limb may be exposed. The splints are light and comfortable; and when combined with suspension make the handling and control of the limb very satisfactory (Fig. 332). Suspension is secured by means of an overhead frame (Fig. 332*a*).

For the treatment of fractures in the bones of the stump of an amputated limb, a peg may be passed through the bone, and traction applied to the lower fragment by weight and pulley (Fig. 333).

Continuous Traction.—*Weight and pulley traction* is the most effective means for securing constant corrective extension. When the tendency to overriding persists, in the case of the femur, and in oblique fractures of the

shaft of the humerus, and of the two leg bones, *continuous extension* becomes necessary. This is applied usually by means of adhesive strips laid on the limb and connected below with traction weights of metal or bags of shot or sand. This method of extension was devised and perfected by Samuel

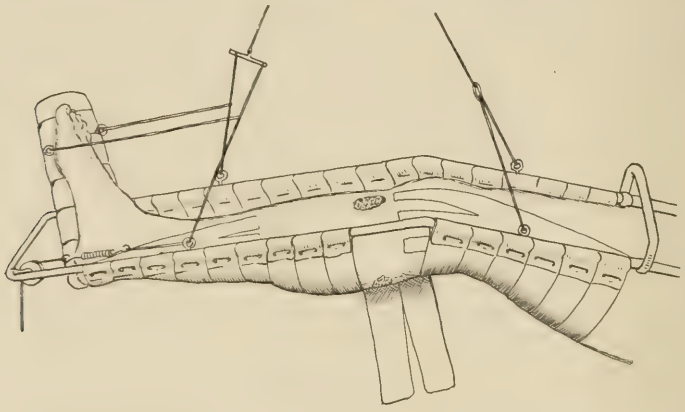


FIG. 332.—FRAME SUSPENSION SPLINT ARRANGED FOR DRESSING COMPOUND FRACTURE. Safety pins hold the strips of bandage.

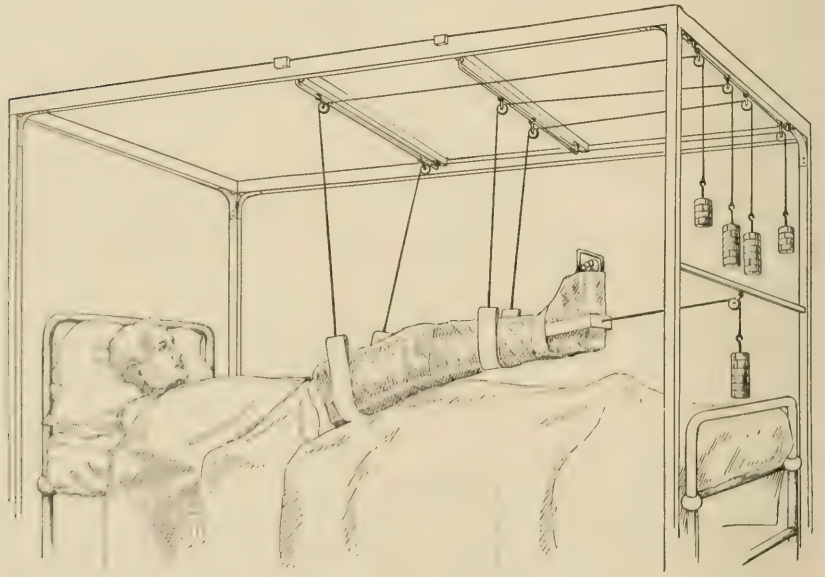


FIG. 332*a*.—BED FRAME FOR SUPPORTING SUSPENSION SPLINTS. By weights and pulleys, which may be placed in any position, traction may be made to meet any requirement.

Gross and Gordon Buck. The best material for the side straps is adhesive "mole-skin." This is slightly heated over an alcohol flame to make it more adherent, and applied to the dry, hairless skin while warm.

A good plan is to use a strip which is cut into obliquely in such a manner as to give the effect of a series of straps diverging from a central strip. One

of these on either side of the limb should extend fully as high as the fracture, and should be folded under and leave the skin preferably above the first joint below the fracture. If the fracture is but a short distance above a joint the plaster will have to be attached to the skin below as well as above

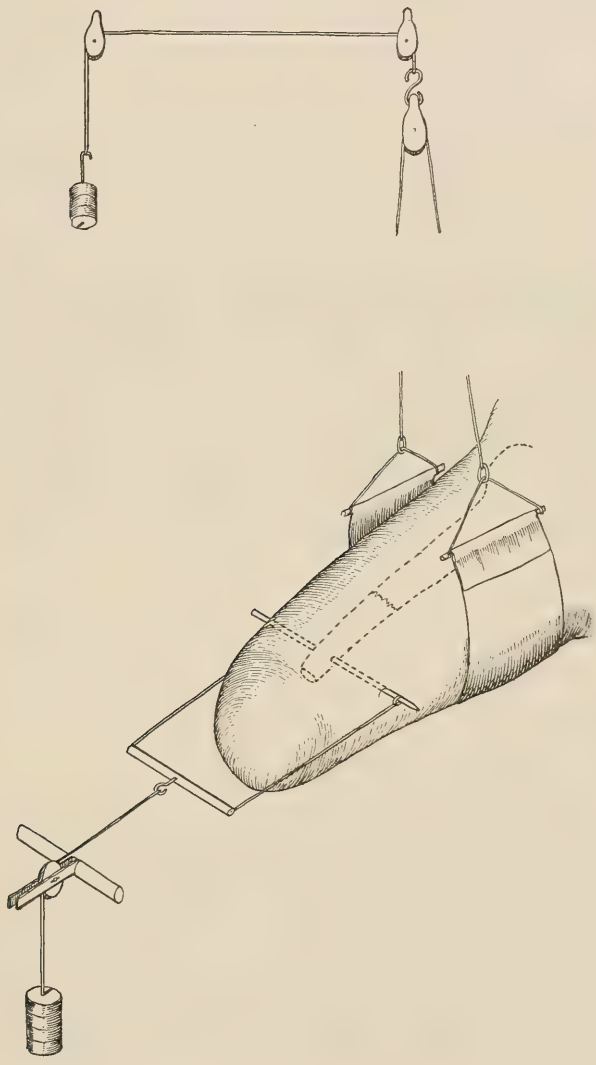


FIG. 333.—TRACTION AND SUSPENSION APPLIED IN CASE OF AMPUTATION AND FRACTURE IN THE STUMP.

The stump is supported by suspension apparatus. A pin is passed through the lower fragment for the application of traction.

in order to give sufficient adhesive surface for it to hold. Or each strip may be divided into three longitudinal strips, the middle one of which is applied parallel with the leg and the two others obliquely (Fig. 334). The side strips having been applied and retained by a flannel bandage, the

weight and pulley apparatus should be adjusted, and weight added before splints are applied.

For applying traction to the femur in case of fracture, the following technic may be followed. This same technic applies to other bones and to traction for other purposes.

A snug, white cotton stocking should be drawn on over the foot and leg; it should be cut off at the level of the knee-joint. Two pieces of surgeon's

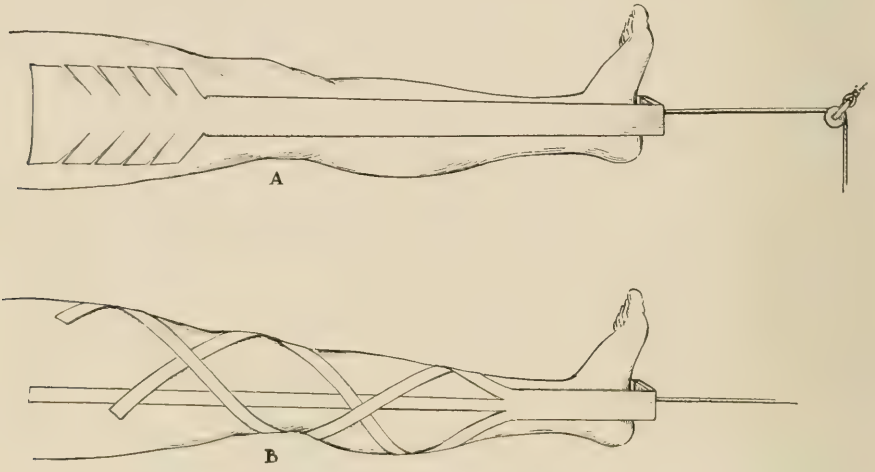


FIG. 334.—EXTENSION STRIPS OF ADHESIVE CLOTH APPLIED.

Showing two methods of application. *A*, makes traction on femur. *B*, makes traction on knee joint and femur. *A*, is to be preferred in fracture of the thigh. These strips should be covered with a flannel bandage to hold them in place. A bandage or stocking should first be applied over the foot and that part of the leg to which it is desired the plaster should not adhere.

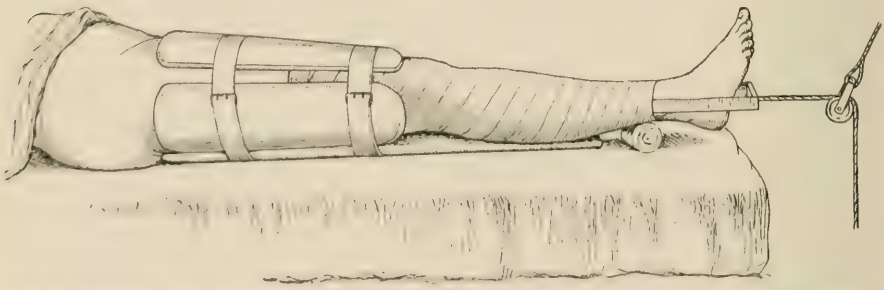


FIG. 335.—SPLINTS ARE APPLIED TO FRACTURE OF THE SHAFT OF THE THIGH IN CONNECTION WITH THE TRACTION.

adhesive plaster 13 cm. (5 inches) wide and 20 cm. (8 inches) longer than the distance from the fracture to the sole of the foot, should be used for the extension apparatus. These strips should be cut into diagonally at their upper ends, which are to be made to adhere from the fracture to the top of the tibia, one on the outer and the other on the inner side of the thigh. Some surgeons apply these strips along the whole length of the broken bone, above as well as below the fracture. From a mechanical point of view this defeats traction, but gives the advantage of splint action of the soft parts. In

adjusting any form of traction the knee-joints should be spared as much as possible from strong pull as the ligaments may be damaged by it.

From the knee-joint down, the strips are to be folded in 3.25 cm. (1¼ inch) in on either edge, the two edges meeting in the middle, making the strap double in thickness, 6.5 cm. (2½ inches) wide, and leaving no adhesive surface exposed (Fig. 334*A*). If there is much hair on the thigh it should be shaved. The plaster strips are laid on and held close to the skin by a flannel bandage or by the leg of a cotton stocking pulled up over them. They are not applied below the knee because of the harm of continuous extension to the knee ligaments.

At the sole of the foot should be placed a piece of wood, 6.5 cm. (2½ inches) high and a little longer horizontally than the widest distance between the two malleoli. This should have a hole in the middle to receive a piece of

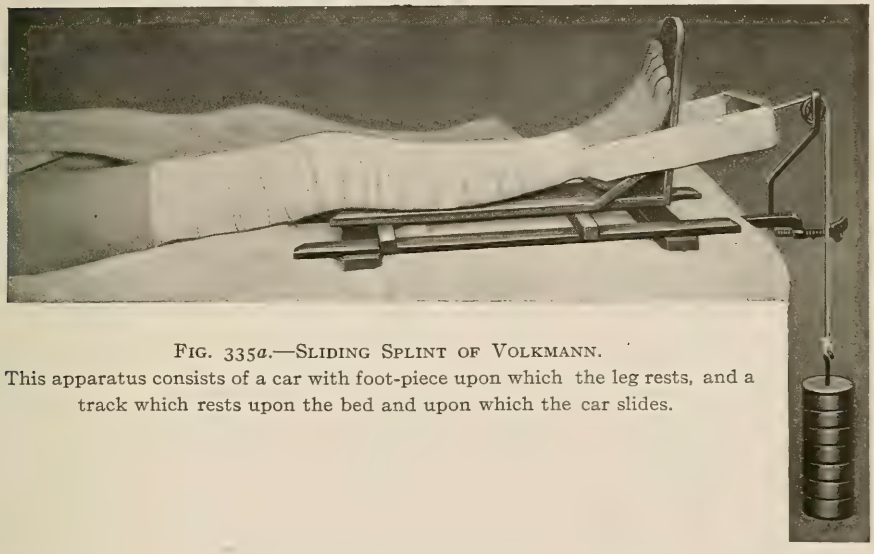


FIG. 335*a*.—SLIDING SPLINT OF VOLKMANN.
This apparatus consists of a car with foot-piece upon which the leg rests, and a track which rests upon the bed and upon which the car slides.

sash rope. The two lower ends of the adhesive side strips are carried across this spreader and made fast to each other on the opposite side by sewing, or by means of a pin. Or the adhesive surface of the two ends may be left free, and fastened to one another by adhesion with the aid of an accessory strip to bind together. This foot piece ahould be as close to the foot as possible.

The following splints are then adjusted and held in place by straps: a posterior splint reaching from the tuberosity of the ischium to the middle of the calf, and an external, an anterior and an internal splint, each about the length of the shaft of the femur (Fig. 335). These should be padded with gauze on towels smoothly spread out. The rope from the spreader is then carried over a pulley at the foot of the bed, and a weight attached. If the bed has an iron frame, the special iron pulley apparatus may be used. A bed having a wooden footboard may have a hole bored through the latter and a pulley screw inserted. In some instances it is more practical to attach the pulley to the wall or to some nearby object.

A long side splint is then applied. If there is but little tendency to outward rotation of the foot it may extend beyond the foot and have a cross

piece 15 cm. (6 inches) long fixed to its lower end to counteract the slight outward rotation. If there is a decided outward rotatory tendency, the leg and foot should rest upon a sliding foot piece (Fig. 335*a*) which runs on a track. This car and track apparatus is not always to be recommended. The foot is bandaged to the foot piece of the car, abundant padding being placed behind the leg, heel and under the foot. The long side splint is padded at its upper and lower ends, and held in place by a broad chest binder, pinned in front. At the thigh it may be held by two webbing straps. Below it is

FIG. 336.—LONG SIDE SPLINT ADDED IN CASES OF FRACTURE OF THE SHAFT OF THE FEMUR. A pillow should support the heel, or the leg may be placed on the sliding support.

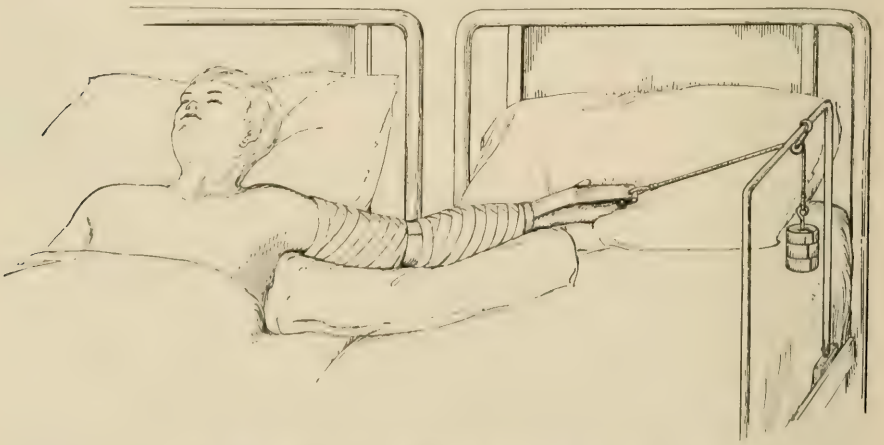


FIG. 337.—SHOWING TRACTION APPLIED TO THE ARM.

held lightly by a single band and left free to play through a slot or lie against the side of the foot piece of the car. The foot of the bed should be raised 30 or 45 cm. (12 or 18 inches) (Fig. 336). The tendency to outward rotation must be constantly watched. The padding behind the heel is very important.

If the soft structures are not too thick, the fragments can be felt to slide into place, and weight should be added until satisfactory position is secured. A common error is the employment of too little weight. The time to apply the maximum weight is immediately. An additional 5 pounds on the

first day will do what 10 pounds will fail to do five days later. To measure the limbs and order 5 pounds more weight, repeating this two or three days later, and still again until ten or twenty days have elapsed before the last addition of weight is made, is not good surgery.

This principle of extension may be applied either to the upper or lower extremities. In the arm the traction may be made by elastic pull or by weights (Fig. 337).

The *measurements* of the legs to determine the degree of shortening and the effect of traction is an essential part of the treatment. The wrong way to make these measurements is much described in text-books. To hold the end of a tape measure in one hand and apply it to the anterior superior spine of the ilium while the other hand applies it to the inner malleolus is to invite inaccuracy. The tactile sense is blunted. The proper way is not by feeling but by sight. The patient should be placed evenly in bed; a straight line should pass down the middle of the body and at right angles to a line connecting the two anterior superior spines of the ilium (Fig. 338); the two legs should bear the same relations to this line in abduction, flexion and rotation. The surgeon should then find by sight and touch a certain easily recognizable point on the anterior superior spine of the ilium, and make a mark with ink or pencil on the skin. The same thing should be done at the internal malleolus. Then going to the other side of the bed, the identical same points should be carefully recognized on the other side of the body, and the skin marked at each one. The distance on the respective sides between these points should be found by a steel tape measure and noted. The figures on the tape measure should not be seen until the point is marked. These measurements may be made both before and after the extension is put on.

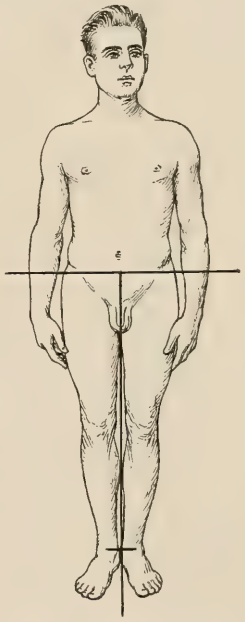


FIG. 338.—LINES AND POINTS FOR COMPARATIVE MEASUREMENTS IN DETERMINING THE RELATIVE LENGTH OF THE LOWER EXTREMITIES.

Pillow extension is an effective means of applying traction to the leg. It may be used in simple or compound fractures. The leg is put up with a dressing of gauze and cotton, bandaged on from the foot to the knee. This makes a thin smooth dressing. The leg is then laid lengthwise on an ordinary bed pillow. The heel is just at the lower end of the pillow. The sides of the pillow are then brought forward around the leg to form a casing and the pillow is bandaged snugly to the leg, forming a firm cylinder. A folded strip of strong cotton cloth is then pinned to the inner and outer sides of the pillow, making a loop across the bottom of the foot, and passing far enough below the sole to have room for the introduction of a wooden block to which a rope for traction may be attached. Chaput (Presse Médicale, Sept. 30, 1914) applied this method with much satisfaction.

Wire traction from the skin is applied by passing a silver wire through the skin and deeply into the subcutaneous tissues and applying the traction to the wire. This method may be used by passing the wire through the pulps of the ends of the fingers or toes to make traction on the digits. Or for traction on the hand or foot the wire may be passed through the thick-skinned

parts. Silver wire is unirritating; and, if the traction that is required is not great, it does not cause pain. The wire should be passed through the tissues in the direction in which the traction is to be made, otherwise it may cause necrosis and cut its way out.

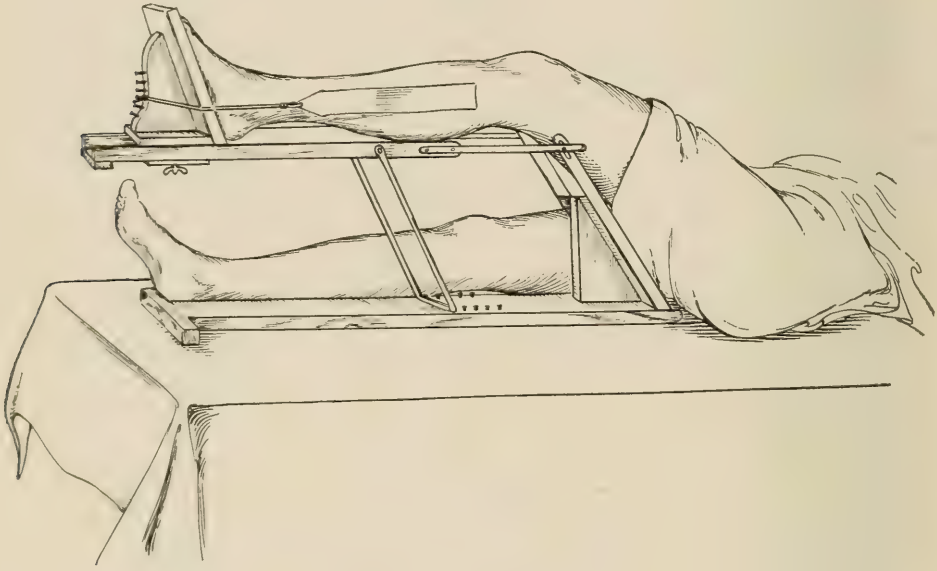


FIG. 339.—LEVER TRACTION FRAME OF ZUPPINGER.
Traction is made by the weight of the limb.

FIG. 340.—AUTHOR'S METHOD OF ELASTIC EXTENSION APPLIED TO FOREARM.
The arm should be bandaged to the splint. The forearm may be fixed in pronation. This is a type of splint of which there may be many modifications. A rubber elastic band or a spiral metallic spring may be used. Or a weight may be attached to the cord passing over a second pulley at the elbow.

Pneumatic extension may be secured by applying air cushions around the lower leg, holding them with a bandage, and making traction through a strip attached to the latter. Two hot-water bags, inflated with air, serve the purpose. In place of air cushions a bicycle tire or the inner tube of an automobile tire may be used.

The lever traction frame of Zuppinger (Beitrage Klin. Chir., vols. xlix and lxiv, pp. 176–178), introduced in Kroenlein's clinic at Zurich, employs

the force of gravity, acting through inclined planes. It is applicable to fractures of the femur and leg (Fig. 339).

Elastic extension may be applied to the extremities by using rubber elastic or a spiral spring, conveying its pull through a cord passed over a pulley fixed to a wooden splint. The splint may be a straight splint or a right-angle splint. The latter is made of wood 1.25 cm. (½ inch) thick. The pulley is placed at the lower end; and the cord is attached to the adhesive straps which are fastened to the limb (Fig. 340). This principle may be applied to the leg as well as the arm. The advantage of using the pulley is that the splint may be made much shorter.

Elastic extension may be used in any apparatus in the place of weight and pulley. By attaching the elastic or spiral spring to the frame of the bed, it may be used in treating fractures of either extremities.

Nail extension is the name given to traction applied through nails, pegs or drills driven into the bone. It was worked out by Codivilla (1903) and Steinmann (1907). This is the only method whereby the traction is applied directly to the bone and not through the intermediary soft parts. If the nails are driven at right angles into one side of the bone only, they are apt to become loose. The most satisfactory results are secured by passing the drill entirely through the limb. The hard part of the bone should be used. If the peg is passed through the cancellous end, near the joint, it rapidly produces pressure necrosis. The shaft, near the terminal enlargement, is the most resistant part.

For making traction on the lower fragment of the femur the peg is best passed through the bone about a hand's breadth above the knee-joint; in the leg, it should pass through both bones just above the malleoli. Pegs should be driven as far from the fracture as possible. The operation should be done with strict asepsis, as a number of fatal infections have been reported in connection with this method. It should not be adopted as a routine measure, but should be reserved for special cases and be applied only by the most competent surgeons, who know the anatomy of the parts involved and can control their asepsis.

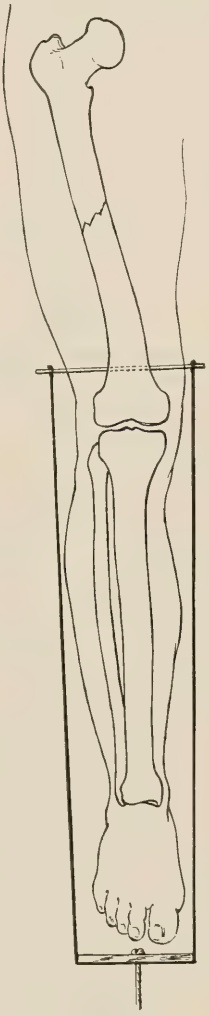


FIG. 341.—NAIL EXTENSION BY METAL PIN PASSED THROUGH LOWER END OF FEMUR.

Slight anesthesia is desirable. Pain does not continue. It is best to drill the bone rather than drive a nail directly through it. The drill may be left in place, projecting from either side of the limb. Or it may be withdrawn after the hole is made in the bone, and a simple rod of iron passed through. For drilling through parts covered by a thickness of muscle, a trocar and canula may be thrust down to the bone, the trocar removed and the drill passed through the canula. A sharpened rod is then passed through the drilled bone and the soft tissues of the other side of the limb. The ends of the rod should be scrupulously dressed, and

connected with the cords for traction (Fig. 341). Extension is needed only until a callus is formed, and then the peg may be removed. For the femur a weight of about 30 pounds is used. By the end of a week this may be reduced to 12 or 15 pounds. The nail should not be left in the bone longer than thirty days. Nails driven in obliquely on each side of the bone do not become loosened and displaced as do nails driven in at right angles (Fig. 342).

FIG. 342.—NAIL EXTENSION BY OBLIQUE PINS DRIVEN INTO THE BONE

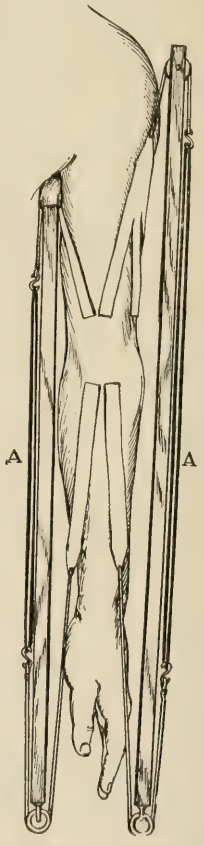


FIG. 343.—THE AUTHOR'S METHOD OF CONTINUOUS DIVULSION BY ELASTIC FORCE.

A, Rubber elastic bands. This splint apparatus is held in place by a bandage which lies under the elastic bands.

The same principle is employed by using an apparatus similar to *ice-tongs*. This is especially applicable to the femur. A small wound is made just above the condyles on either side, and the tong driven into the bone. The two arms of the tongs are held together by a bandage. A dressing is applied about the wounds. The traction cord is fastened to the handles.

Continuous Divulsion.—A separating force, applied in both directions, may be used in place of traction. The same methods of attaching the force to the limb are employed as for traction; but instead of making the attachment to the distal fragment only, it is made to the proximal fragment also.

Adhesive plaster may be used, or pegs driven in the bone, or any other method. It is applicable to any of the long bones. Elastic force (Fig. 343), the screw principle (Fig. 344), weights and pulleys, or combinations of these may be adapted to this mechanism.

Divulsion apparatus may be incorporated in the plaster-of-Paris splint, and by screwing apart the two casings alinement may be regulated and overriding prevented (Fig. 344*a*).

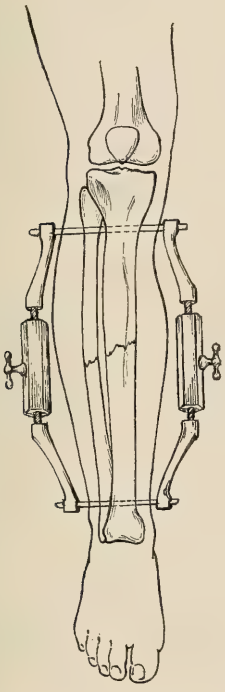


FIG. 344.—THE AUTHOR'S METHOD OF DIVULSION BY BONE PINS AND SCREW.

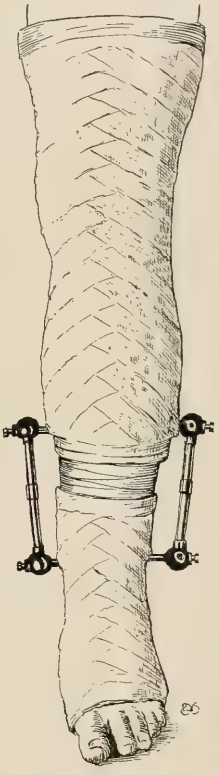


FIG. 344*a*.—FRACTURE CLAMPS OF HACKENBRUCH.

The clamp is incorporated in the plaster-of-Paris case which is interrupted at the fracture. By screwing the clamps, separation may be increased. The skin under the plaster must be protected by padding before the splint is applied.

An **apparatus for moving bones** in any direction or for holding them was devised by W. E. Schroeder (Jour. Am. Med. Assoc., June 26, 1915). It is used in open operations. A clamp grasps each fragment, and by means of screws the clamps may be moved longitudinally, making divulsion or approximation, and laterally, making transverse replacement (Fig. 345). This apparatus is especially adapted to holding fragments in place while they are being fixed by plates, pegs or other fixation measures; but it may also be used to make correction in cases in which other measures are not necessary; or it may be left on for several hours or days while callus formation is proceeding. For this latter purpose, the holding jaws should be so con-

structed that they may be released by a screw which should bring them in line with the shaft, and allow their later removal without the necessity of any further retraction or cutting in the wound.

This apparatus is a modification of the single two-jawed bone clamp of Lowman which is capable of holding and manipulating a broken shaft (Fig. 346).

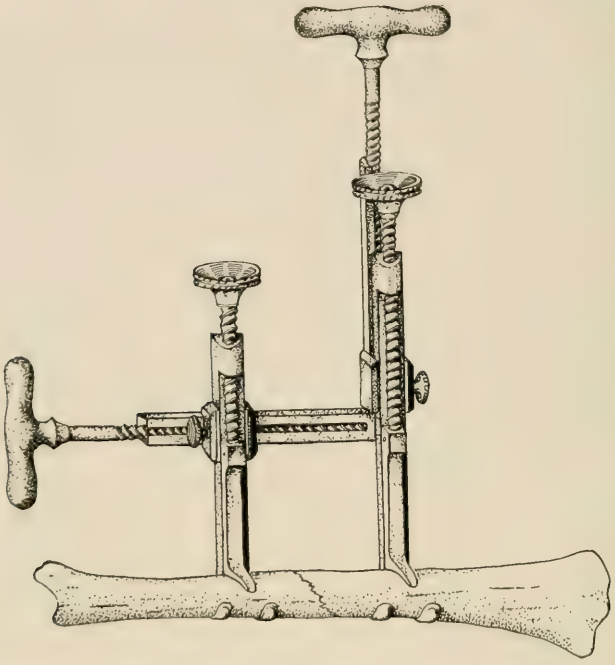


FIG. 345.—APPARATUS FOR HOLDING AND MOVING BONE-FRAGMENTS IN ANY DIRECTION.

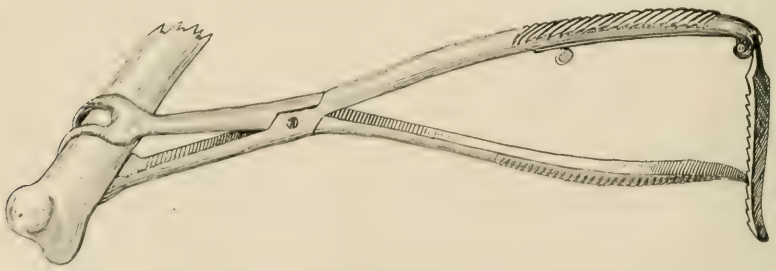


FIG. 346.—FORCEPS FOR HOLDING AND MANIPULATING BONE.

Transverse Traction.—In many cases of fractures of long bones, especially in the femur, but also in the humerus and leg, longitudinal extension or divulsion does not suffice; and because lateral displacement continues, some pressure transverse to the long axis of the bone is necessary. Bardenheuer has worked out apparatus to meet these requirements in all situations (Fig. 347). Traction to cause rotation may be combined with simple lateral traction (Fig. 348).

Adhesive plaster should not be thrown around a limb for transverse traction excepting in special cases. The circulation of the limb should be protected.

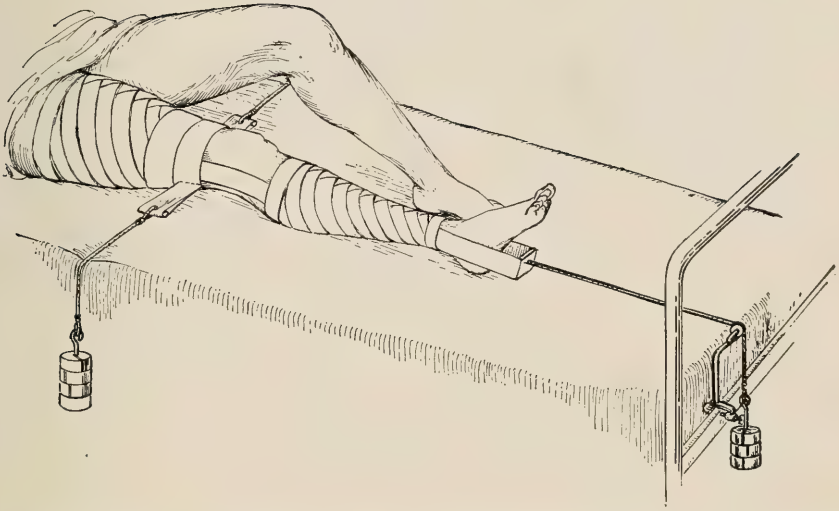


FIG. 347.—LATERAL TRACTION, COMBINED WITH LONGITUDINAL TRACTION, TO CORRECT LATERAL DISPLACEMENT AND OVERRIDING

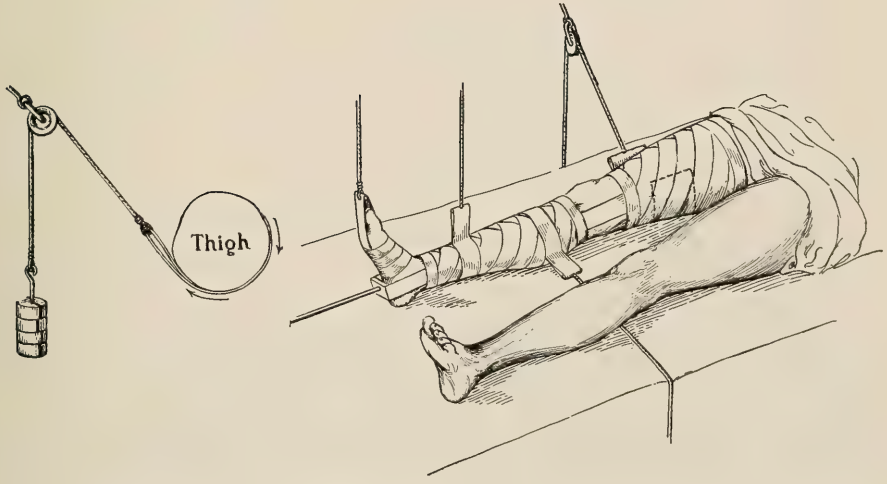


FIG. 348.—LONGITUDINAL EXTENSION, LATERAL AND VERTICAL TRACTION, AND ROTATION APPLIED TO LOWER EXTREMITY.

For this reason a well-padded flannel band is best. It may be stiffened by the addition of adhesive plaster. Or a piece of paper board may be curved about the limb, and adhesive plaster applied to it. The same principle is equally useful in fractures of the leg (Fig. 349).

Transverse traction is equally useful in the upper extremities (Fig. 350). Lateral traction in the upper part of the thigh is employed especially in fractures of the neck of the femur.

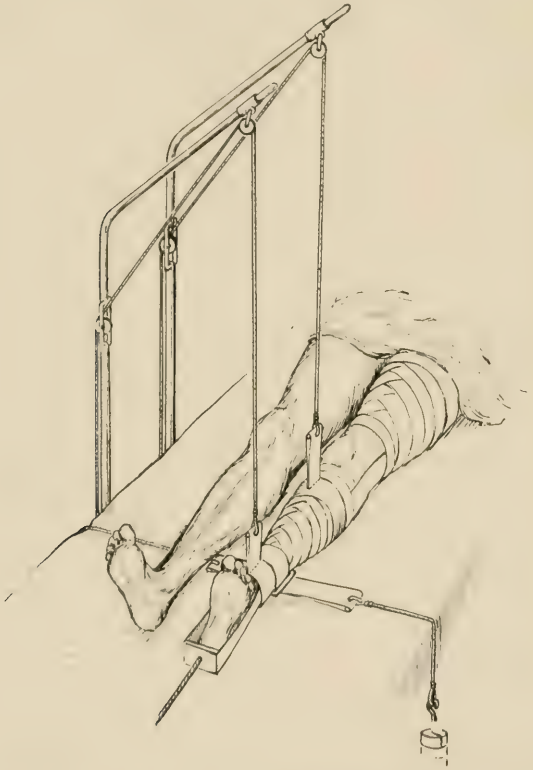


FIG. 349.—EXTENSION AND ANTEROPOSTERIOR TRACTION TO CORRECT DISPLACEMENT IN FRACTURE OF TIBIA.

Massage in the treatment of fractures has a wide field of usefulness which has been much neglected. There is no doubt but that in the average case immobilization is continued too long—not too long for the good of the bone but too long for the good of the soft tissues. Attention is naturally directed most zealously to the bone; it is assumed that the soft tissues are not a part of the fracture; and that, not being diseased, the soft tissues require no treatment. It is this fallacious reasoning that keeps the soft tissues immobilized longer than is good for them. As a matter of fact they are not free from disease; they sustain two forms of injury: one is the laceration, contusion, stretching and infiltration about the fracture; and the other is the prolonged and unphysiological immobilization incidental to the treatment of the fracture. Every surgeon has seen much of the irreparable harm that ac-

crues from prolonged and needless immobilization of the soft tissues in such injuries as fracture of the radius.

As soon as the acute reaction of traumatism has subsided and there is no more bloody and serous oozing taking place into the tissues, massage, electricity, or alternate applications of heat and cold should be applied to imitate in a measure the natural functions of the soft tissues. If this is not done, the muscles atrophy, the circulation and nourishment of the part are im-

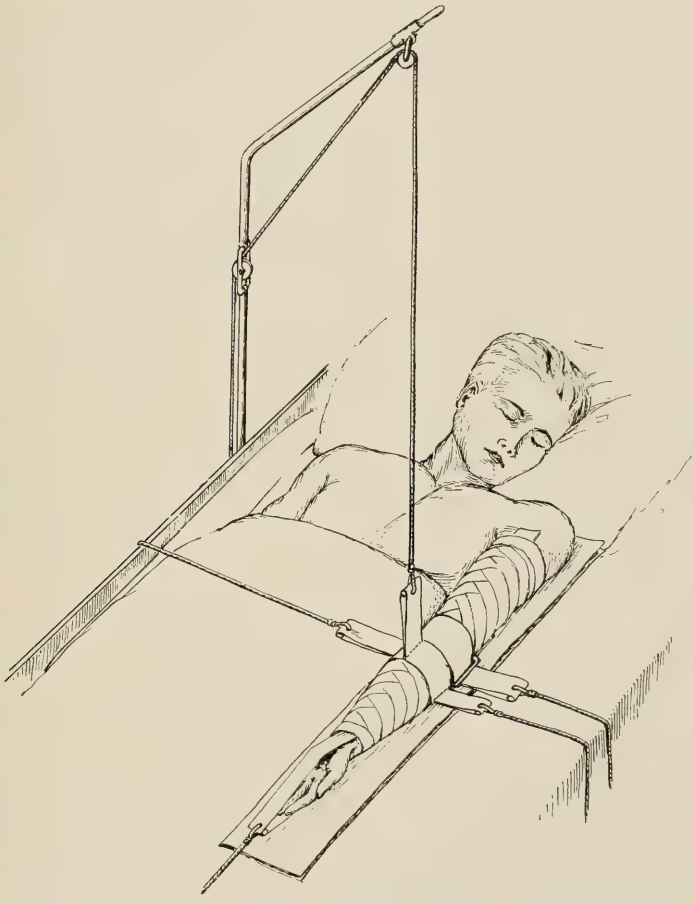


FIG. 350.—EXTENSION AND ANTEROPOSTERIOR TRACTION TO CORRECT ANTERIOR DISPLACEMENT OF LOWER FRAGMENT IN FRACTURE OF HUMERUS.

paired, nerves are damaged, the lymph channels are clogged with waste products, and infiltration of the tissues with serum and cellular elements aggravates the local disorder.

Massage, gently applied, so as to effect only the soft tissues, is of great value. It should at first be the merest stroking of the skin. The bone, if there is mobility, should be held by splints or extension. With skill the massage may have its force increased. It should never be applied in such a way as to cause bony motion at the fracture, but should only affect the soft parts. It need not be forcible. The reflex action of the rubbing of the

skin is capable of stimulating the underlying tissues. In the case of bones in which there is not mobility, more force may be used. Rubbing toward the heart should be the rule.

This applies to all fractures of bones of the limbs. Fractures of the arm, elbow, forearm, thigh, knee, leg, hands and feet—all are benefited by massage; or, more properly, the patient is benefited. Especially in fractures in which there is little or no mobilization of the bone, such as of a single bone of the forearm or of the fibula, massage can be of great help if applied every day or every second day. It not only keeps the soft parts in a normal state but by so doing hastens the consolidation of the bone. It is true that this treatment often requires much pains, and will not be resorted to because of the expense entailed; but in order to get the best results and the quickest restoration of function it should be applied. It is conceivable that such measures will find a wider field when surgical treatment is not practised for pecuniary profit but rather for the one specific object which gives it its social value: namely, the restoration of damaged organs and parts safely, expeditiously, painlessly and permanently to a normal state of health; the supreme interest of the patient being the object of surgical endeavor.

OPERATIVE TREATMENT

Operative treatment and **direct fixation** of fragments is indicated when, despite the best efforts, the fragments cannot be brought into satisfactory apposition.

Operation should not be done until the surgeon has made use of all of the possibilities of non-operative treatment. The surgeon should not rush to the operation too fast. Deficiencies in nonoperative treatment should not always be remedied by operation, but preferably by more efficient non-operative treatment. The surgeon should ask himself, has everything been done? General anesthesia, traction, manipulation, countertraction, pressure, counterpressure, the rubber ischemic bandage, the application of exact anatomic knowledge, *x*-ray examination, and comparative measurements—all have something of help to offer. An exact anatomic result need not be expected in all fractures. The *x*-ray should guide, but not misguide. If there is apparent good position, and function is restored, the treatment may be regarded as successful even though the *x*-ray shows that the position of the fragments is not accurately restored. Bone, covered by a mass of soft tissues, is not comparable to a piece of wood or metal in a mechanic's hands.

There are certain cases in which the natural contour of the parts can not be restored; there is noticeable deformity. In such cases function may be restored perfectly, but there may always be doubt as to the outcome. If competent surgery can be brought to bear, operation should be done. In oblique fracture of the tibia, with fracture also of the fibula, operation will often be necessary to restore the natural length and form of the leg, unless traction by means of bone nails is successful. Operation is indicated in most fractures of the patella. In fracture at the junction of the upper and middle thirds of the humerus, damage to the musculospiral nerve is so apt to occur that the well-equipped surgeon is always justified in operating to secure exact apposition. Fracture of the lower jaw is often entitled to the same treatment.

No rules can be laid down. Some surgeons insist that every fracture in which exact apposition cannot be secured by other measures should be operated upon. This is good surgery, provided that the surgeon who operates has anatomical knowledge and skill, can control absolutely his asepses, and obtains good results. Operating on such fractures is good

surgery, if good surgery is done. But to promulgate the doctrine that all such fractures should be operated upon by all surgeons is bad teaching and worse surgery. It is just as bad as to promulgate the doctrine that fractures should not be operated upon because in some hands the worst result that can be obtained by nonoperative treatment is better than what might result from operation. It should be borne in mind that neither surgeons nor fractures are constant factors.

When other resources have failed, the well-equipped surgeon is justified in exposing the fracture, and applying such local treatment as the condition requires. The best time for such operation is from the fifth to the tenth day after the accident, when traumatic reaction has subsided. In bones near the surface, such as the patella and olecranon, operation may be done on the second or third day. Fractures with pressure or visceral injuries require immediate operation. The incision of operation often liberates an amount of blood and serum, the presence of which has been an obstacle to reduction. The removal of soft tissue which has fallen between the bone-ends can then be accomplished. Often nothing further is required. When the surgeon feels that neither splints nor extension will hold the fragment in place he should proceed to the direct fixation of the bone-ends. The fracture should be exposed by a longitudinal incision and free access secured. Loose fragments of bone should be removed. Sometimes it suffices to fit the end of one fragment into the other. This can be done by engaging a sharp end of one fragment into the medullary canal of the other (Fig. 351) or into a notch sawed in the bone-end. In making a tenon and mortise, consideration should be given to the direction in which displacement tends to occur. I have secured some perfect functional results in the femur by inserting the sharp point of one fragment into the medullary canal of the other, closing the wound, and applying a splint.

FIG. 351.—SHOWING METHOD OF HOLDING FRACTURE OF LONG BONE IN APPOSITION BY IMPACTING ONE FRAGMENT ON POINT OF OTHER FRAGMENT.

In dealing with *comminuted fractures with irreducible displacement*, after extension, manipulation, anesthesia and tenotomy have failed, the same general principles as before stated apply. Here the surgeon often has to do with loose fragments of bone which have become entirely separated, and often so displaced as to form the chief impediment to reduction. Such fragments may either be replaced, or, if not too large, removed.

Bone suturing has a wide field of applicability. Sometimes the bones can be satisfactorily held with heavy sutures of chromic catgut or kangaroo tendon. Sutures made of the patient's own fascia may be used. A band of woven catgut answers the same purpose as a band of fascia.

For bringing together torn fascia and periosteum without penetrating the bone, absorbable suture material is best. By sewing together the soft structures about the fracture, the bones can often be held in position. When it is necessary to penetrate the bone, absorbable sutures may rarely be used. For this purpose metal is better.

Wiring is useful when strong soft tissues for suturing are not available. All wire tends to become loose. It will never again be as tight as when first applied, because it causes absorption of bone.

Silver wire is not good as it breaks too easily. Wire made of aluminum

bronze is the best for bone wiring. The ordinary iron wire of the hardware store is also useful. For holding the fragments with wire, the bones should be drilled and the wire placed in such direction as to control the tendency to displacement (Figs. 352 and 353). Or the wire may be used to encircle the bone (Fig. 354).

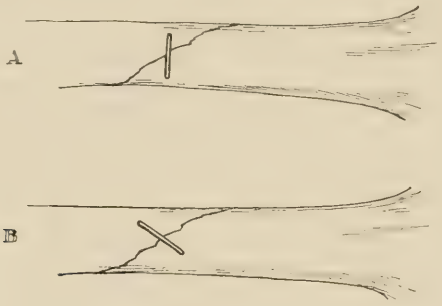


FIG. 352.—WIRING BROKEN BONE.
A, Wrong way; *B*, right way.

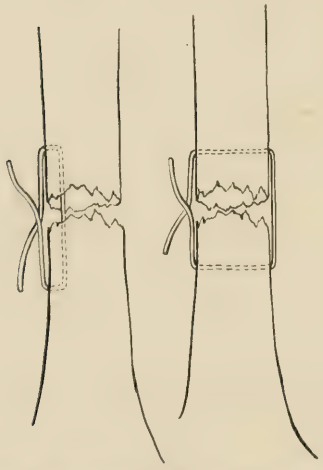


FIG. 353.—METHODS OF WIRING BROKEN BONE.

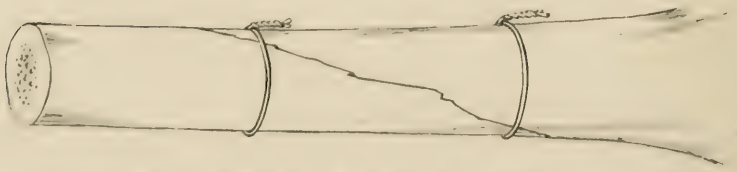


FIG. 354.—CIRCULAR WIRING OF BROKEN BONE.

The best result is secured if some sort of mortising or bony engagement is used in addition to the wiring. The wire having been passed it is twisted clockwise, each strand around the other (Fig. 355), and the ends cut long enough not to untwist, and pressed down against the bone. Instead of twisting the wire, the ends may be brought through a nut and held by a screw (Fig. 356).

It is a mistake to plan to leave wire or any other metallic foreign body permanently engaged in bone. It is pretty sure to make trouble sooner or later. The wound should be closed, care being taken to suture the periosteum

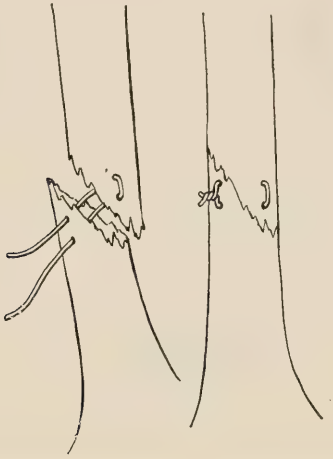


Fig. 355.—Wire Passed Through Bone and Twisted to Hold Fracture.

Fig. 356.—Wire Around Bone Held by Nut and Screw.

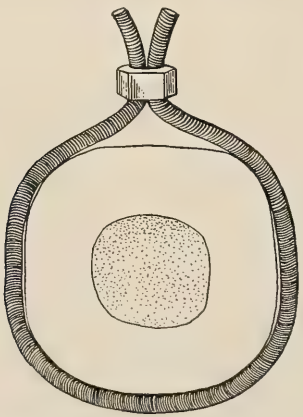


Fig. 357.—Threaded Wire Around Broken Bone Held by Nut.

and other soft tissues about the bone. The skin wound is closed, unless it has seemed best to allow the ends of wire to emerge, and a dressing applied. Often it is feasible to apply a small dry dressing, then a plaster case, then cut a fenestrum, and add a larger dressing to the wound (see Compound

Fractures, page 518). After union is secured the wire is untwisted and removed.

Wire, having a thread, upon which a nut could be screwed, has been employed. Such devices were perfected by Lambotte and Putti (Clin. Chir., Milan, June 30, 1914) (Fig. 357). Putti, F. W. Parham and E. D. Martin perfected metallic bands, the application of which requires a special apparatus. The bands are made of steel, and vary in width from 3 to 5 mm.

FIG. 358.—OBLIQUE FRACTURE HELD WITH METAL BANDS.

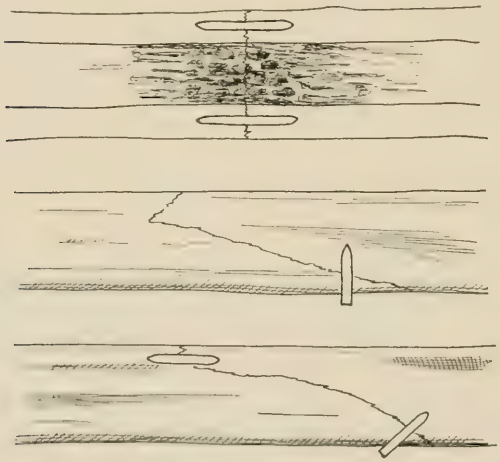


FIG. 359.—PEGS AND PINS OF BONE AND IVORY EMPLOYED IN THE TREATMENT OF FRACTURES.

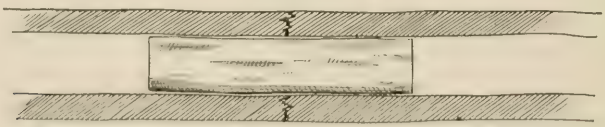


FIG. 360.—DOWEL OF BONE INTRODUCED IN MEDULLARY CANAL TO PREVENT DISPLACEMENT OF FRACTURE.

This piece of bone may be taken from the adjacent bone or it may be heterogeneous.

(Surg., Gyn. and Obst., Nov., 1916). They are of use especially in oblique fractures, but may be used to hold plates in transverse fractures. The fracture is exposed by longitudinal incision and the band passed around the bone. If it is intended to leave it permanently, the periosteum should be elevated; if not, it may be placed on the periosteum. Two bands suffice. The wound is closed and dressed, and the limb put up in plaster (Fig. 358). These metallic substances are not the ideal fixation, but they may be applied more quickly than bone grafts, they are stronger, and require less skill.

Nails and **pegs** of bone, ivory and metal are also used for direct fixation. These are of special value in fractures of the tibia, fibula, radius, ulna and neck of the femur. They may be introduced in the wound of open operation,

or through the skin. The latter method requires that a trocar and canula be passed down to the bone in the direction in which the peg is to be driven; the trocar is removed, a drill passed in the canula, and the bone drilled; the drill is then removed and the peg passed into the canal thus made (Fig. 359).

Bone ferrules and **cylinders** were made by Senn from the tibia and femur of the ox. These were perforated and decalcified and used by slipping them over the two fracture ends or into the medulla. They become absorbed in time. F. H. Albee (New York Med. Jour., May 23, 1914) most successfully made inlay bone grafts, taking the inlay from the fractured bone

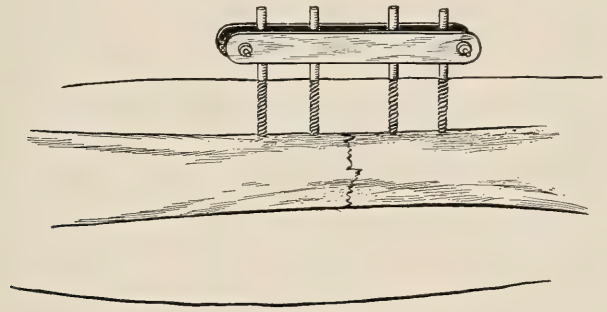


Fig. 361.—Clamp and Screw Method of Holding Fracture.
This is a modification of the plates of Parkhill.

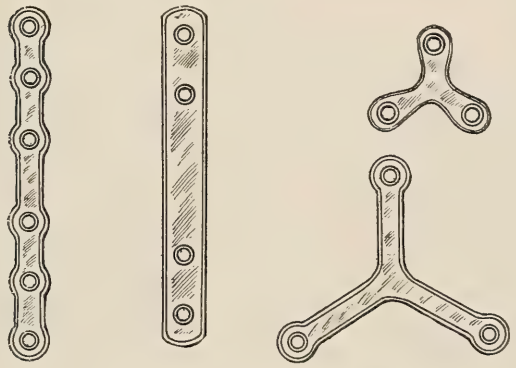


Fig. 362.—Metallic Bone Plates of Lane.

and placing it in a gutter in each fragment. This is the best of all of the fixation methods. Cylinders of bone and ivory are also introduced into the medullary canal (Fig. 360).

Screws and **plates** have been used in many forms. L. Freeman (Jour. Am. Med. Assoc., Dec. 18, 1909) devised a clamp, made of two plates lined with wood, which holds four screws. The clamp lies outside of the tissues. The screws may be inserted through the tissues. A trocar and canula may be passed to the bone, and the drill and screw passed through the canula (Fig. 361). This is the principal of the Parkhill plates.

Plates of metal for the fixation of fractures were introduced in surgery by C. Parkhill. The plates are fixed to the bone by screws, and are removed after union is secured (Annuals of Surg., vol. xxvii, p. 553). The operation may be done any time during the first ten days. It is best not done after

the second week as callus is established. Some surgeons prefer to operate during the second week, keeping the fracture well immobilized previous to the operation. The method is equally applicable to simple and compound fractures.

A. Lane popularized the plate method, and worked out minute details for the operation. The greatest care to prevent infection is exercised. Mr. Lane's rules require that no bare hands come into contact with the instruments. Even gloved hands or any part of an instrument that has been touched by gloved hands should not come into contact with the wound. There should be a minimum amount of manipulation. As little periosteum as possible should be stripped from the bone. The bones are held by bone hooks and retractors. Plates of vanadium steel, provided with four to eight screw holes, are used. Steel screws, threaded to the heads, are driven through the hard part of the bone. An embracing clamp, which grasps both bone-ends and also holds the plate while it is being screwed, is a great help (Fig. 362). The plates are placed on the periosteum. Holes for the screws are made with a drill, care being taken not to make the holes too big. No screw is introduced nearer than 7 mm. (¼ inch) to the line of fracture. One or two plates are applied across the fracture (Fig. 363). Experience demonstrates that these plates easily work loose. Many surgeons now prefer a plate which is slightly pliable. Silver, about 3 mm. (⅛ inch) thick and 1.25 cm. (½ inch) wide is much used.

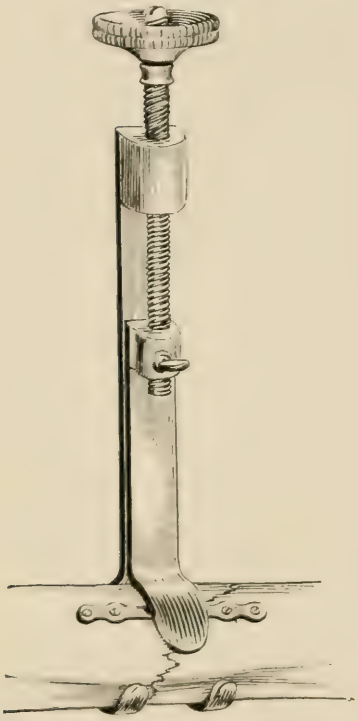


FIG. 363.—METHOD OF ATTACHING PLATES TO BROKEN BONE.

The bone holder grasps the plate while it is being screwed in place and holds the bone fragments at the same time. Such a plate can not be depended upon to hold a fracture. The usual immobilization apparatus must be applied in addition.

After the plate is applied, the soft tissues are sutured over it, the wound closed and splints put on. It should be borne in mind that the plates are not intended to hold the bones. That must be done by the splint. The plate simply gives support and helps to prevent displacement. If much motion is allowed the screws are easily loosened or the plate broken. The plates are cut down upon and removed after union of the bone has taken place.

Mr. Lane and some other surgeons went so far as to apply these plates to every fracture in which an exact reduction can not be obtained without operation. This meant most fractures. They secured admirable results, better, in fact than had ever before been attained by any other method of treatment.

The published results of the treatment of fractures by the use of buried metal plates are admirable. The unpublished results are horrible. The method was so warmly advocated by skillful surgeons, and their excellent results given such wide publicity, that the method was extensively

adopted. In some states it was made a part of the statute law, and in matters of workmen's compensation, surgeons are entitled to collect ten dollars more for the treatment of a fracture by plating than for treating the fracture without plating. I have no hesitation in saying that, at the present time, this surgical expedient is doing more harm than good. This is not because of any inherent lack of merit in the method; but because of an inherent lack of method in the determination of surgical fitness. Infections, suppuration, loss of limbs and loss of life are by no means uncommon results of the treatment of simple fractures, which once were treated without hazard.

The use of non-absorbable foreign materials in the local fixation of fractures is not to be resorted to if the surgeon is equipped and capable of utilizing autogenous absorbable materials, such as bone-grafts or fascia, or if heterogeneous absorbable materials will serve the mechanical purpose.

Metal in contact with bone causes rarefaction and absorption of the bone. It is an unsurgical and makeshift expedient.

The **operative treatment** of fractures cannot be made amenable to fixed rules, but as near as can be stated the following principles, applying both to simple and compound fractures, adults and children, may be followed by the well-equipped surgeon:

1. Simple fractures in which the fragments can be adjusted so that a good functional result will be secured, need not be operated upon even though the *x*-ray shows that perfect apposition has not been secured. If, after a fracture is healed, it could be discovered only by the *x*-ray that a fracture had been present, the surgeon and patient should be satisfied with the result.

2. When it is probable that union will not take place or will be long delayed on account of the interposition of soft tissues or because of the impossibility of immobilization, operation is indicated.

3. The interposition of loose bone fragments is not an indication for operation except as it falls under one or the other of the above rules.

4. The serious injury of important nerve trunks or blood-vessels calls for operation.

5. Fracture, complicated by the injury of viscera, which injury itself alone would call for operation, should be exposed. This applies especially to fractures of the skull, spine and pelvis.

6. The most satisfactory operative treatment, if any direct fixation device is necessary, consists in the introduction of a graft of bone taken from the patient's own skeleton. This method should supersede all of the devices for direct fixation which employ metals in contact with the bone. Next in value to this is the use of absorbable heterogeneous material, such as bone, catgut and tendon (see Bone Grafting).

TECHNIC OF BONE GRAFTING IN FRACTURES

The Sliding Graft.—This may be used in any situation in which material may be secured. The bone fragments are exposed and held in exact apposition by clamps. With the double circular saw a strip is cut extending onto either fragment. The cut should be one-third longer on one than the other. The shorter piece is removed. The longer piece is slid across the fracture. The short piece is placed in the unfilled gutter at the end of the long piece (Fig. 364). The free pieces of bone may be held in their grooves by pegs of bone or by sutures of chromic catgut or kangaroo tendon (Fig. 365). It is possible to cut the sliding piece with a bevel so that it will

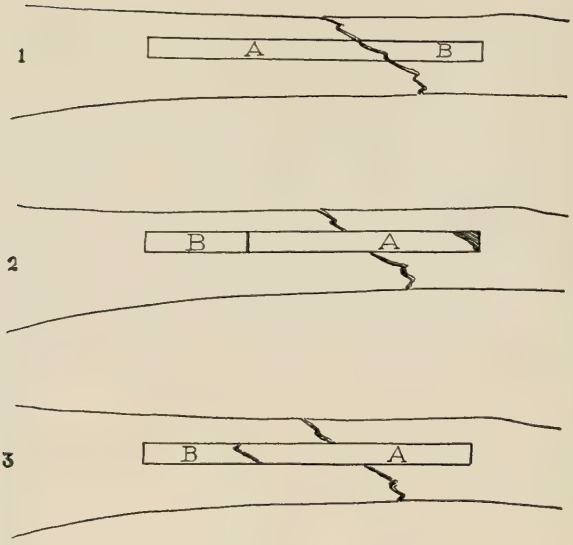


FIG. 364.—SLIDING GRAFT INLAY.

(1) The fragments are held in exact apposition and the pieces *AB* are cut out. *B* is picked out and *A* is slid across the fracture.

(2) The angular end of *B* is cut off and it is replaced at the other end of *A*.

(3) By removing both *A* and *B* from their bed they may be reversed and replaced as here shown.

FIG. 365.—ALBEE'S METHODS OF HOLDING BONE-GRAFT IN PLACE WITH SUTURES AND PEGS.

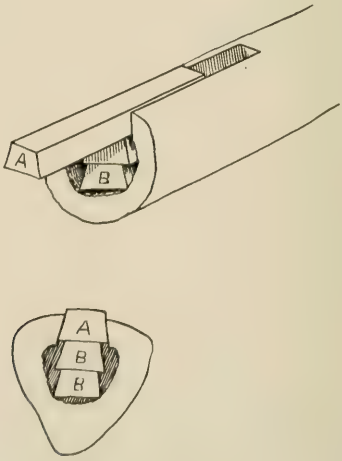


FIG. 366.—METHOD OF HOLDING SLIDING BONE-GRAFT IN PLACE.

The graft *A* is cut on a bevel; the shorter piece is removed, cut into pieces *B*, and one or two of these shorter pieces pressed into the marrow cavity to support the longer graft which spans the break.

not come out. The short piece may be used as a plug for the marrow canal to prevent its displacement into the canal (Fig. 366). The long piece may be inserted in the canal, and its displacement prevented by placing a shorter piece above it (Fig. 367). A graft may be used in a groove in one fragment and as a pin in the other.

Transplanted Grafts.—Transplanted grafts are best taken from the patient's tibia. They should be of good length. A graft should rarely be less than 13 or 15 cm. (5 or 6 inches) long. In operating for non-union, the graft should not be shorter than 10 cm. (4 inches). (For the technic of cutting such grafts see Operations on Bones, page 772.) They may be cut of any

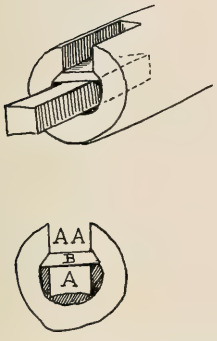


FIG. 367.—METHOD OF HOLDING BONE-GRAFT IN PLACE TO CONNECT THE TWO FRAGMENTS.

The dowel *A* has been cut from the space *AA*, and inserted in the marrow canal; its displacement is prevented by the smaller pieces *B*, one of which is inserted in each fragment.

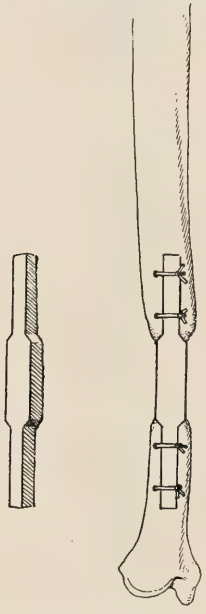


FIG. 368.—BONE-GRAFT INSERTED TO COMPENSATE FOR FRACTURE WITH LOSS OF SUBSTANCE. (*After Albee.*)

size or shape to meet the needs of the situation. When bone-ends do not meet as in old ununited fractures or in fractures with loss of substance, the graft may be made long enough to span the gap (Fig. 368).

Such grafts may be cut with pointed ends and the groove which is excavated to receive the graft may be undercut to prevent the escape of the transplant (Fig. 369).

In operating for ununited fractures with some displacement of one fragment a gutter may be made on one fragment and the graft may serve as a pin in the other. For taking a square graft, a square hole may be made by drilling four holes at the corners and cutting out the intervening segment with a chisel (Fig. 370).

Fracture of the clavicle is amenable to this treatment by inlay bone grafting. The skin flap which exposes the bone should be made by a curved incision so that the skin wound does not lie on the bone wound (Fig. 471).

Fracture of the humerus may be treated by a pin in the marrow cavity or by an inlay (Fig. 372).

Fracture of the olecranon may be treated by a sliding inlay graft (Fig. 373 and 374).

Fracture of the forearm, especially of the ununited type, may be treated by inlay grafting.

Fracture of the neck of the femur, if it requires operative treatment, is best fixed with a pin of bone taken from the patient's tibia. Pins, nails and pegs of metal are inimical to the health of the bone, and should not be used if the surgeon is capable of making an autogenous bone peg.

FIG. 369.—DAVISON'S METHOD OF HOLDING TRANSPLANT BY ENGAGING ENDS UNDER CORTEX OF BONE.

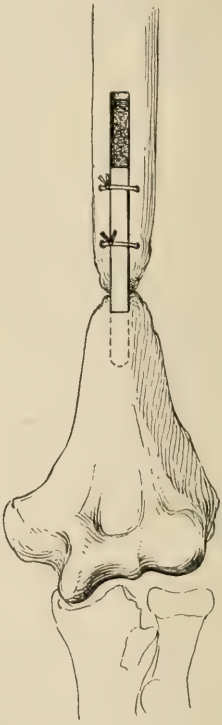


FIG. 370.—GRAFT USED TO UNITE FRAGMENTS IN CASE OF NON-UNION IN OLD FRACTURE OF HUMERUS.

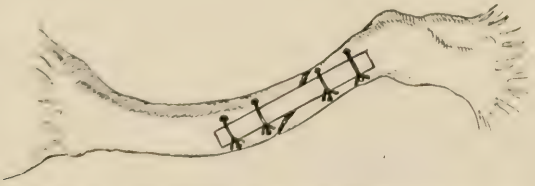


FIG. 371.—INLAY GRAFT IN TREATMENT OF UNUNITED FRACTURE OF CLAVICLE. (*After Albee.*)

The patient should be placed on a table to which he can be fixed and longitudinal traction and abduction applied to the leg and external lateral traction applied to the upper end of the thigh. The front of the joint capsule should be exposed by an anterior incision beginning just internal to the anterior-superior spine of the ilium and passing downward toward the inner side of the femur along the inner border of the sartorius for a distance of 12

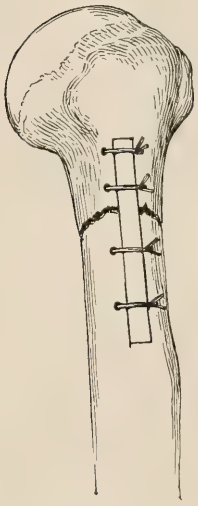


FIG. 372.—INLAY GRAFT IN TREATMENT OF UNUNITED FRACTURE OF NECK OF HUMERUS.

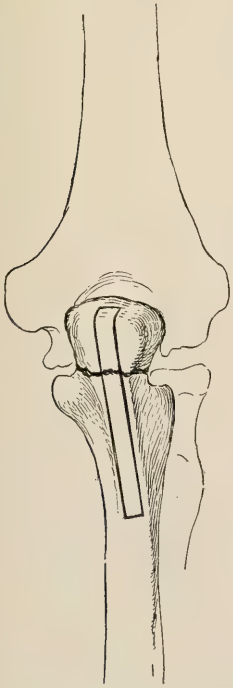


FIG. 373.—SLIDING INLAY GRAFT FOR TREATMENT OF FRACTURE OF OLECRANON. (*After Albee.*)

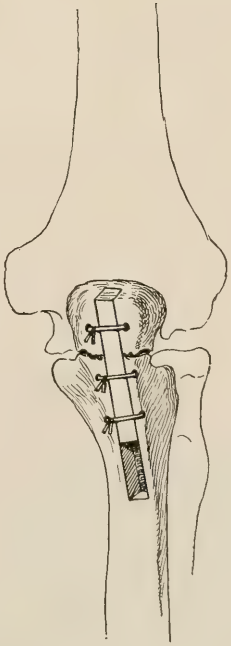


FIG. 374.—INLAY GRAFT MOVED UPWARD TO ENGAGE OLECRANON AND HELD WITH CHROMICIZED CATGUT. (*After Albee.*)

cm. (5 inches) in the adult. The muscle is exposed and retracted outward. The tendon of the rectus femoris is retracted outward and the psoas-iliacus is retracted inward. The joint is opened, soft tissue is removed from between the fragments and the fractured surfaces freshened and placed in position.

To place the fragments in position may require traction and abduction of the thigh. A second incision is then made external to the great trochanter. This should be 5 to 8 cm. (2 or 3 inches) long. The bone is exposed. In

FIG. 375.—MOTOR DRILL COMPLETING THE BORING OF THE CANAL TO RECEIVE BONE PEG IN FRACTURE OF THE NECK OF FEMUR.

The distances and measurements for this operation should be controlled by the radiogram as directed by Albee.

order to ascertain the direction a small hand drill may be used to make a hole through the trochanter and the center of the neck. This direction having been ascertained, the motor drill should be used to make a hole fully 1 cm. (⅜ inch) in diameter. The drill hole should be made with exactness and care. The distance from the trochanter to the fracture should be known from the radiograph. The drill should penetrate the inner fragment nearly to the articular cartilage. If the fragment is small, it is important that the drill should go as far as possible (Fig. 375). Then the motor should

be disengaged from the drill and the latter left in the bone while the peg is made.

The crest of the tibia is exposed and the exact length of the peg marked out as indicated by the scale on the drill. The lines of the peg should be marked with a scalpel. The crest of the tibia should be used. A square peg should be cut. Its largest cross-section should be 1 cm. When the peg is ready, the drill is withdrawn and the peg slipped into the canal. It may be

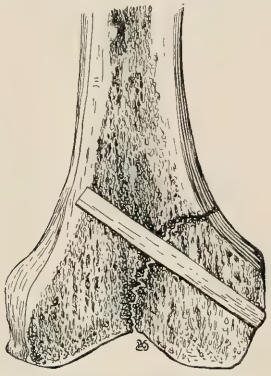


FIG. 376.—METHOD OF USING PEG OF BONE IN FRACTURE OF CONDYLE OF FEMUR.

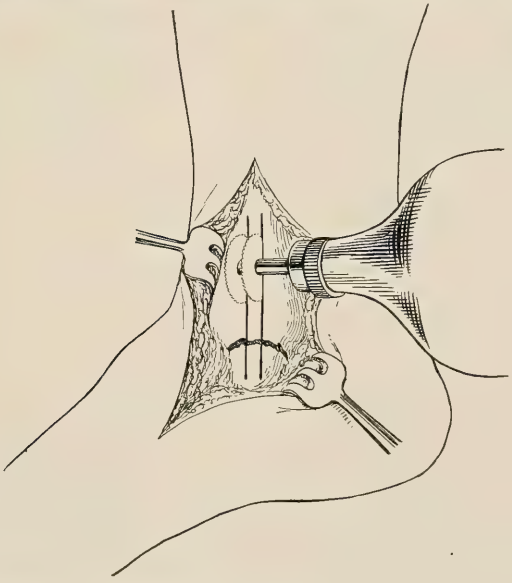


FIG. 377.—UNUNITED FRACTURES OF INNER MALLEOLUS TREATED BY SLIDING INLAY GRAFT.

The lower fragment of graft will be removed and the long upper fragment will be slid down across the fracture.

driven home with a few light taps of a mallet. Albee cut a graft from the tibia and applied to it a lathe connection which is fitted to the motor. This lathe makes the pin round and of the size of the drill.

The wounds are then closed and the limb put up in abduction in a plaster-of-Paris splint extending from the axilla to the toes.

Fracture of the condyles may be secured by pegs (Fig. 376).

Fracture of the malleolus may be treated by graft inlay when it refuses to unite (Fig. 377).

Fracture of the Patella.—The fracture is exposed by a U-shaped incision and the joint cleared of clot. The edges of the torn prepatellar fascia are trimmed of ragged tabs. The prepatellar fascia is dissected back from the front of each fragment. Each fragment is tilted forward and a piece having the shape of a truncated wedge with its base away from the fracture, is cut out with the small circular saw. The bone removed should not involve the whole thickness of the patella, but should leave the posterior articular

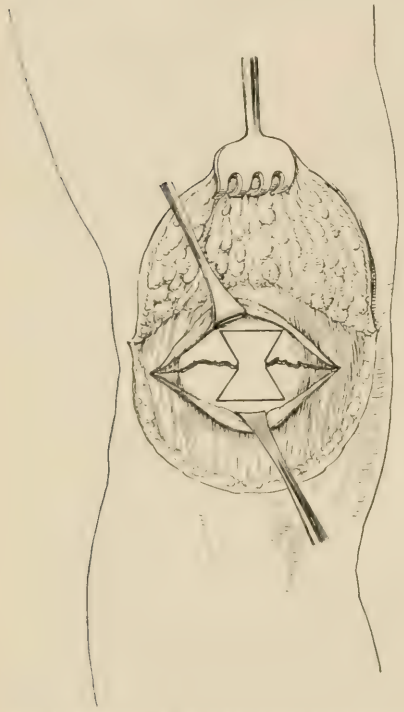


FIG. 378.—INLAY IN FRACTURE OF PATELLA AFTER METHOD OF ALBEE.

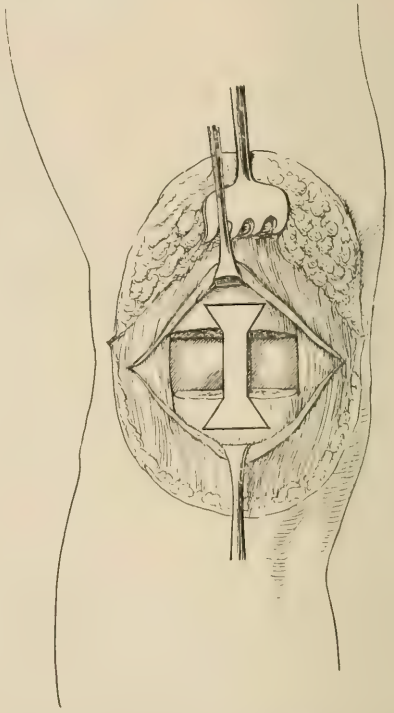


FIG. 379.—INLAY IN TREATMENT OF OLD UNUNITED FRACTURE OF PATELLA WITH SEPARATION AS SUGGESTED BY ALBEE.

surface uncut. The two fragments are pressed together and a piece of sterilized paper is placed on the bone, pressed against the edge of the cuts and a paper pattern made of the opening. This pattern is laid upon the antero-internal surface of the tibia, and a single piece of bone having the shape of the two wedges united is cut with the small circular saw. This piece with its periosteal surface anteriorly is inserted in the patella (Fig. 378). The reflected fascia is then sewed down over the graft and the lateral tear in the capsule sewed, as is described on the operation for suturing the patella (page 598). The limb should be put in a splint for four weeks.

This operation has no advantage over simple suturing, excepting in cases with destruction of the prepatellar fascia.

Albee also cut a graft on a similar principle for old fractures with separation and fibrous union (Fig. 379). Fascia grafting is better treatment here.

In old ununited fractures simple straight grafts may be driven in holes or gutters in the form of an X (Fig. 380).

Fracture of the Os Calcis.—This fracture, when separating the bone into a posterior and anterior fragment, may be treated by boring a tunnel from the posterior surface of the posterior fragment horizontally through the posterior

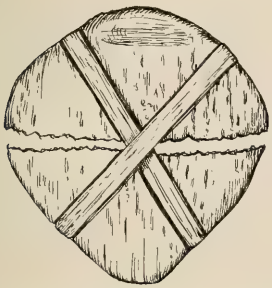


FIG. 380.—DAVISON'S METHOD OF PLACING PEG TRANSPLANTS IN OLD FRACTURE OF PATELLA.

FIG. 381.—FRACTURE OF OS CALCIS TREATED BY AUTOGENOUS BONE PEG.
The tendo Achillis has been divided. (*After Albee.*)

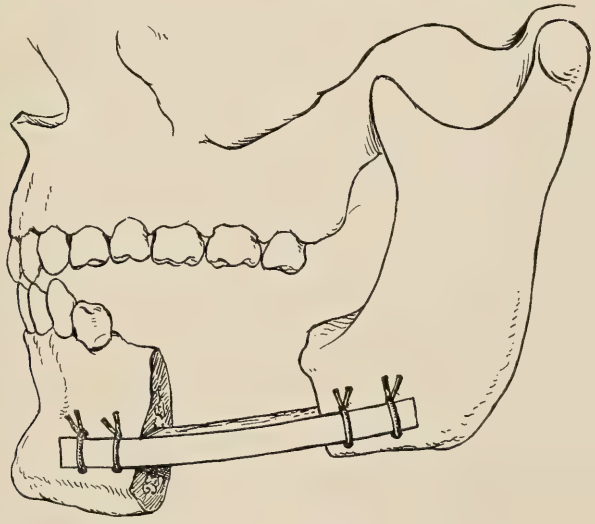


FIG. 382.—FRACTURE OF LOWER JAW WITH LOSS OF SUBSTANCE, TREATED BY INLAY BONE GRAFT.
This treatment alone is not sufficient but should be combined with an interdental splint. At a later operation a second transplant should be inserted to give a better cosmetic result.

fragment and well into the anterior fragment and driving in a peg to hold the parts together. The posterior surface is exposed by an incision, beginning at the outer side of the tendo Achillis just above the bone, and curving downward and outward and then downward and inward to the lower margin of the posterior surface of the heel. The small flap thus outlined is dissected back and reflected inward. The dissection should keep as close to the bone as possible. Through the upper end of the incision the tendo Achillis should

be cut. The tunnel is bored in the bone with the same instrument used for boring the neck of the femur and a similar peg from the tibia is driven into the os calcis (Fig. 381). The flap should be sewed back in place and the foot and leg are put up in a light plaster-of-Paris dressing.

Fracture of the Lower Jaw.—In cases of non-union which have resisted the ordinary methods of treatment, an inlay graft may be used. Bone grafting is also useful in fractures with loss of substance. Here a graft may be used in recent fractures to span the gap (Fig. 382). The fact that the graft is exposed to infection does not militate against its use. Autogenous bone transplants have a great power of resisting infection. After placing such grafts, the jaw should be immobilized, the patient fed and the mouth washed out through a soft rubber tube (see Fractures of Lower Jaw, page 543).

FRACTURES INVOLVING JOINTS

The involvement of joints by fractures adds another element of importance. Here there is an effusion of blood and serum into the joint, and the traumatic exudate about the line of the fracture causes the formation of plastic exudate upon the synovial surface. If the joint is kept immobilized too long, the plastic material becomes adherent to the opposite bone surface and the presence of serum may add to the amount of deposited material. The amount of this material is dependent upon the traumatism, or, in other words, upon the degree of separation and mobility of the fragments. Motion of the joint immediately after the injury increases the amount of exudate and effusion. The guiding principle, therefore, in the treatment of such fractures, is immediate and the most perfect immobilization obtainable. This should be continued until the traumatic reaction has subsided and bony union has taken place. Then passive motion may be undertaken; but so long as there is a possibility of moving one fragment upon another, absolute immobilization should be maintained. During the first few hours after the injury the immediate application of cold will inhibit the effusion. After twenty-four or forty-eight hours, pressure by flannel bandage will often hasten absorption, and at the end of two or three weeks, massage, heat and pressure may be used; but these measures should not be undertaken at the expense of immobilization. In old people ankylosis may follow immobilization; and it should be as short as possible. In young persons it is different. Here good reduction of the fracture is the important thing. When this is accomplished, a joint may be kept immobilized without fear of stiffness being due to the immobilization. The integrity of the joint will not be impaired.

COMPOUND FRACTURES

In the treatment of compound fractures modern surgery has made advances which are not exceeded in any other branch of surgery. In modern hospital treatment it has attained a nearly perfect state. In the general practice outside of the hospital there yet remains much to be desired. In the city within the precinct of a well-equipped hospital, the ordinary ambulance case of compound fracture enjoys the best possible chances that surgery has to offer.

In the treatment of this condition the first thing which the surgeon should have in mind is the wound and the securing of its primary healing. With successful attention directed to this end, the compound fracture is quickly converted into a simple one. The fate of a compound fracture is largely decided by the first dressing. The surgeon may never hope by later scrupulous attention to atone for laches committed at this first dressing. When

a compound fracture is first seen an elaborate attempt at diagnosis and treatment should not be made. The wound should be covered by a copious protective dressing, any extreme deformity corrected, temporary immobilization effected and then carried to a place for dressing. If considerable time must elapse before the wound can be properly dressed, foreign matter should be removed, the wound dried, treated with iodin, and a protective dressing applied at once. The best place in the world for the dressing to be completed is in the operating room of a hospital; one of the worst places is the patient's bedroom. Here the fate of the limb is decided. In a fracture with considerable mobility of the parts or laceration of tissue, a general anesthetic should be given. It is as important here as in any other operation that the patient should be surrounded by the most scrupulous attention to modern surgical details in all that that implies. Gross dirt should be picked out of the wound, wiped away or washed out with alcohol. Blood and dirt should be removed from the surrounding skin with alcohol or ether. Water should not be used if iodin is to be employed. The skin and wound should then be dried with dry sterile gauze and the wound and the adjacent skin thoroughly treated with 2 to 5 per cent. alcoholic solution of iodin. The iodin should be applied to the ends of the bone, to the chinks and crevices of the wound and to the skin for a wide distance around the wound. Correction of the displacement should then be made and the wound dressed.

The best treatment in the absence of iodin or some other penetrating antiseptic is asepsis. In order to secure this, the skin should be scrubbed with warm water and soap for a radius of at least a foot from the wound. This scrubbing should involve every bit of skin, including the wound edge. To exclude the soap suds, a small tight roll of gauze may be pressed into the wound. But the entrance of soapy water into the wound need not be feared; it can be washed out again. While the scrubbing is in progress, to keep the suds washed out, a stream of antiseptic solution is played upon the wound. The same skin is then washed with ether, alcohol or other fat-dissolving fluid. Outside of the hospital it is this cleansing that is usually defective. If the wound has been soiled with earth in a tetanus zone, an immunizing injection of antitetanic serum should be given.

In the case of a small wound with but slight injuries to the soft tissues, the simple painting of the wound with tincture of iodin and the application of an aseptic dressing of gauze, with immobilization, suffices. The small amount of discharge is absorbed by the gauze, the wound becomes occluded by scab, and the fracture converted into a simple one. In no case should the wound of a compound fracture be sealed hermetically, as some surgeons advise. It is best that nature should seal it, if it is to close.

In the case of a larger wound, with multiple fractures or lacerations of soft tissue or irreducible displacement or the presence of foreign matter, the surgeon should freely enlarge the wound, or make such new wounds as shall give the best access for the treatment of these conditions. He should have in mind always the restoration of the parts as nearly as possible to their normal conditions. Fragments of bone, completely separated from their vital connections, should be removed unless of such size that their removal will shorten the limb beyond the point of usefulness. Under such circumstances they should be left with the hope that they may be free from infection. Bleeding vessels should be ligated, torn periosteum restored, divided nerves, muscles and tendons sutured. The wound should be filled with *chloraminated oil* if infective soiling is present. Drainage should be provided in the most dependent parts and the rest of the wound closed if the wound has not been badly soiled and an antiseptic is not used. The most complete

immobilization should be instituted and the general comfort and quiet of the patient looked to.

The elevation of temperature, following the absorption of blood products, should not mislead the surgeon. A rise of temperature characterizes all fractures. Experience teaches the surgeon to distinguish between that which is due to the absorption of aseptic blood products and that which is due to bacterial products. The drainage tubes should be removed as soon as possible. Usually all drainage can be dispensed with by the end of five days. The escape of serous discharges from the tube is not an indication that drainage is necessary. Usually the tubes have outlived their usefulness by the end of the third day. The sooner and more complete the immobilization of the bones, the less will be the discharge. For this reason, if the limb can be put up in plaster at the first or second dressing, with large fenestra, it will be found that the serous discharge is less than when the immobilizing splints have to be removed at each dressing.

Every one who has had experience in this line of surgery has seen in what extreme degrees of laceration the tissues can be restored to place and limbs saved, which at first sight seemed hopeless. Even yet, however, the pessimistic impression of these wounds is responsible for the sacrifice of limbs. Surgeons should not be more appealed to by the prospect of a nice, well-rounded stump than by the prospect of a tedious series of dressings of a compound fracture. There is never an immediate necessity for amputation in a compound fracture in which there is a possibility that the limb may be saved. It is better to wait until the signs of gangrene have appeared in ten limbs than to amputate one limb which would not have become gangrenous.

A compound fracture requires the same treatment as a simple fracture, plus the treatment of a wound in which extraordinary precautions against infection should be taken, because if bone becomes infected some part of it is apt to perish and become a foreign body, and because infected bone is one of the slowest and most difficult tissues in the body to heal. In the treatment of compound fractures the surgeon has to guard against and often treat all of the complications to which wounds are susceptible.

For the treatment of infected and suppurating compound fractures see Infected Wounds (pages 212 and 237) and Inflammations (page 228).

After a compound fracture has healed, if there has been infection and suppuration, there is much stiffness, induration and weakness of the part. It can always be predicted that these conditions will improve. Time, use of the part, improvement in general health and massage, have the power to convert a bad-looking limb into a strong and supple member.

Conditions Calling for Amputation.—Three conditions arising in compound fractures justify *amputation:* (1) injury to the blood-vessels so great as to cause the death of the part; (2) uncontrollable infection which is threatening the life of the patient, and (3) irreparable and wide loss of bone substance so great as to render the limb useless. The ability of modern surgery to cope with these three conditions marks the advance of science. The suture and grafting of blood-vessels, the prevention and treatment of infections and the transplantation of bone make possible the saving of a majority of the limbs such as were amputated fifty years ago without hesitation. In some cases it is evident at the first examination that the injury to the vessels is irreparable and the parts below the wound must become gangrenous. In such cases the extremity is found to be cold and livid. The main vessels may be found divided or thrombosed. Pressure upon the skin or nails does not show the return of blood to the capillaries from which it was expressed; or it may be impossible to make a pale spot upon the cyanotic

skin by pressure. In such cases amputation should be done if the circulation can not be restored (see Thrombosis and Embolism, and Gangrene).

On the other hand, examination may show the extremity to be cold and the main artery pulseless, but if all the signs of death of the part are not present, the surgeon should endeavor to save the limb, inflicting as he proceeds with the examination and dressing, the least possible traumatism, and, finally, applying the bandages loosely as possible (see Gangrene, page 315; and Thrombosis and Embolism, page 454). In all cases an effort should be made to preserve the extremity unless it is unquestionably beyond saving. Nor even then is immediate amputation always called for. If the patient is suffering from shock, extreme depression or anemia, or if other conditions are present which render the continuation of operation hazardous, the parts should be cleaned, hemostasis secured, a large dressing applied and further operation deferred. If circular compression is used to control the hemorrhage previous to amputation, it should be applied as low down as possible, preferably directly over the wound, as the vitality of the tissues below the pressure is much impaired, and flaps involving such tissue are more prone to slough.

When in a compound fracture, notwithstanding free incisions, abundant antiseptic treatment, because of some constitutional or local condition, uncontrollable infection persists and septicemia threatens the life of the patient, amputation well above the infected area should be performed. The same operation is necessary when, through local disturbance to the blood-supply, infection causes a gangrene of the extremity. Amputation is also indicated in cases in which there is so much destruction of bone that, in order to bring the bone-ends together, the limb must be shortened to such a degree and the soft tissues so folded as either to render the limb less useful than an artificial substitute or to give rise to gangrene because of angulation of the vessels. In cases such as this an effort should be made to save the limb by means of an osteoplastic operation or by the transplantation of bone to fill the defect. These rules apply especially to the lower extremities. The arm is of greater value. The hand should never be sacrificed except as an extreme measure. The whole humerus has been removed and the forearm articulated to the scapula, giving a serviceable hand.

Although every effort should be made in the direction of conservative surgery, still there is a fourth class of cases in which amputation is indicated. These are the cases in which, in order to preserve the limb, a long and trying period of treatment must elapse, with continuous suppuration and confinement, all of which must have a depressing effect upon the health of the patient, and end in securing only an imperfect limb. The age, sex and occupation of the patient, the location of the injury and the adaptability of prosthetic apparatus to the particular part, should be taken into consideration; and, finally, with a full understanding of the case, the patient himself should be called upon to elect the course which should be followed.

FRACTURE DISLOCATION

Fracture dislocation, or dislocation complicated with fracture into or near to a joint, should be treated by the combination of the principles laid down for the treatment of the two different conditions. First an effort should be made to correct the dislocation. This should be done carefully and not persisted in if not easily accomplished. In some instances it has been taught to allow the fracture to unite and then give attention to the dislocation. This is positively bad surgery. Delay is sure to result in much exudate and fixation of the dislocation in its false position, which can

be corrected ultimately only by open operation. The best time to operate is at once. If the dislocation is not easily reduced by manipulation, further traumatism of this sort should not be inflicted, but the joint should be cut down upon, the dislocation reduced, and the fracture given any attention which it may require at the same time. This is one of the serious operations of surgery, and infection should be zealously guarded against. (Special fracture-dislocations are discussed under each particular joint.)

AMBULANT TREATMENT OF FRACTURES

By the ambulant treatment of fractures of the lower extremities we shall understand the application of splints which allow the patient to use both legs in walking. Other methods for getting patients out of bed and about with canes and crutches will be described under special fractures. Ambulant splints may be employed in fractures of the thigh, leg, and foot. The principle of their employment is that, in connection with the immobilization of the fracture, the weight of the body in walking is carried upon some support above the broken bone. In fractures of the leg the body-weight may be borne by the bony prominences of the knee; in the femur the splint, carrying the body-weight, receives the weight at the perineum and ischium.

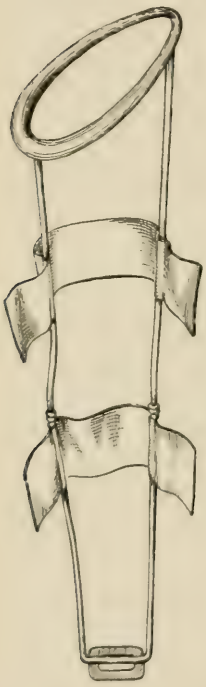


FIG. 383.—SPLINT FOR AMBULATORY TREATMENT OF FRACTURES OF LOWER EXTREMITY.

Traction is made by adhesive strips connected by elastic extension to foot piece.

Splints to accomplish this are made of metal, somewhat after the style of the orthopedic hip and knee splints. An excellent apparatus of this kind is so constructed that extension is applied through adhesive straps passing down to elastic bands or springs connected with the bottom of the splint. Two iron bars, connected by a crosspiece 6 cm. (2½ inches) below the foot, pass up the sides of the leg to a ring which support the perineum and ischium (Fig. 383). Between these rods are straps and bands for encasing and immobilizing the fracture. With a lift under the sole of the shoe of the sound side, the patient with a broken thigh is enabled to walk about with the aid of canes or crutches. For fractures of the leg a similar apparatus is used excepting that the body-weight is supported by a cushioned pad pressing just below the enlargement of the knee.

Ambulatory splints, embracing these principles, may be made of plaster-of-Paris. For fractures of the leg the plaster splint is applied in the following manner:—The first step consists in the reduction of the fracture and the cleansing of the skin with soap and water. The leg should then be covered with powder (such as boric acid and zinc stearate), and a white cotton stocking drawn on. A padding of ten or twelve layers of cotton wadding is bandaged to the sole of the foot with a flannel bandage. This should be very loose and about 4 cm. (1½ inches) thick. The plaster bandage is now applied from the toes to just above the knee in the manner already described (page 477). The plaster should be well rubbed in to give a strong splint. It should be especially smooth and firm about the knee, making a little more pressure here than the ordinary plaster splint. A piece of wire netting 5 cm. (2 inches) wide is incorporated in the plaster, beginning above the fracture

on one side, passing down the leg, under the sole and up on the other side. A sole-piece of wire may also be added. The sole is also strengthened by additional layers of plaster. When this plaster case has become hardened, it is seen that the leg is suspended. When the patient steps upon the sole of the splint the thickness of the cotton beneath the foot separates the sole of the foot so far from the sole of the case that the foot, attached to the lower fragment, hangs suspended in its plaster shoe. Thus the weight of the body, which otherwise would fall upon the foot, is borne by the diverging surfaces of bone above the fracture (Fig. 384). I have applied this splint in many cases at periods varying from six hours to two weeks after the injury with fairly satisfactory results (J. P. Warbasse; Treatment of Fractures of the Lower Extremity, Annals of Surgery, xxvii, May, 1898).

The same principle may be applied to fractures of the thigh. In this case the splint is carried up so as to enclose the pelvis. Traction is made through adhesive straps held under the sole by elastic tension. At night when the patient lies down the ordinary weight extension may be connected at the foot of the bed.

The advantage of the ambulant splint is that it enables the patient to be up and about either for hygienic or economic reasons. It has the disadvantage that much more skill is required in its use—skill which can be acquired only by experience. The treatment should be controlled by *x*-ray observations. Watchfulness is also necessary lest pressure troubles develop. My advice is that the surgeon should try it until he has mastered the technic of its use, and then employ it in such cases as demand it.

FIG. 384.—AMBULATORY TREATMENT OF FRACTURE OF LEG WITH PLASTER-OF-PARIS CASE.

Note that the sole of the foot does not rest upon the bottom of the splint but is suspended above it. Drawn from case applied by author.

LENGTH OF TIME FOR THE HEALING OF FRACTURES

The length of time required for the healing of fractures varies with the bone, the nature of the fracture, the manner of treatment and the nourishment of the part. Union is strong enough for splints to be dispensed with in fractures of the lower extremities two or three weeks before the leg is strong

enough to bear the weight of the body. In general it takes from four to six weeks in the upper extremities and from six to eight weeks in the lower extremities, for firm consolidation to take place. This may not be strong enough, however, to warrant use of the limb. Before the part is used the surgeon should grasp the bone firmly and see if motion at the fracture still exists. If the slightest bending is possible, more time should be given (at least two weeks) before the part is put to use. The examiner should not be deceived by the yielding of soft tissues into thinking that motion is present when it is not.

Soft union should not prevent a patient with a broken leg from going about on crutches. With a light splint on the injured leg and a slight lift on the other shoe he may go about his business. It is during the first three or four weeks that extension, quiet and accurate splinting are essential. By that time the callus acts as a splint and angular deformity is the chief thing to be guarded against.

COMPLICATIONS OF FRACTURES

Complications are the less characteristic symptoms, or the rarer conditions which may arise but which do not occur with sufficient frequency to be regarded as symptoms.

Immediate complications may require special treatment aside from the ordinary treatment of the fracture. *Comminution*, *impaction* and *dislocation* have already been described or will be described under special fractures. *Lacerated muscles* often require suturing. Pulpified muscle, in compound fractures, should be cut away. *Injuries to viscera*, such as the brain, in fractures of the skull, and the bladder, in fractures of the pelvis, are considered elsewhere. Large *blood-vessels* may be lacerated and give rise to a diffusion of blood through the tissues or to hematoma, causing so much pressure as to hinder the circulation and threaten gangrene of the limb beyond. In the latter event the injured vessel should be exposed and ligated or sutured and the compressing hematoma removed. Laceration of lymph trunks may cause *lymphedema* which requires treatment. The pressure of *displaced bone* against the *vessels*, threatening gangrene, should be corrected at once either by anesthetization and manipulation or open operation. *Nerve injury*, resulting in continuous pain or paralysis, may be due to compression, stretching or laceration; but if the pain or paralysis persist after the best possible reposition of the fragments has been secured, then the nerve should be exposed and the cause of the trouble dealt with. Sometimes a small displaced fragment of bone will be found impinging on the nerve and causing pressure. If the nerve is lacerated it should be sutured. *Impaction*, causing shortening or distortion should be corrected by pulling the bones apart. If it does not cause objectionable shortening it is desirable as securing immobilization. *Separation of the epiphysis* should be recognized in order that parents may be advised of the possibilities of shortening of the limb.

Later complications, coming on during the healing of fractures constitute a large catalog of widely different conditions requiring treatment. If pressure from the effusion of serum is great it may be relieved by elevation of, the limb, by bandaging or by multiple incisions. After a limb has been bandaged for a long time *edema* is observed when the bandage is removed. Usually this edema does not call for any special treatment, but its subsidence may be hastened and the comfort of the patient increased by massage. A flannel bandage from the toes or fingers up, firmly and evenly applied, will control the swelling when the limb is allowed to hang. After a while, with the assistance of massage, the vessels become stronger and the swelling

disappears. *Ulceration, sloughing* and *gangrene*, due to the constriction of bandages or pressure of splints are complications to be guarded against. Dressing materials should not be wound about a broken limb but should be applied lightly in folds or longitudinally. The bandage which holds a dressing should never be tighter than the flannel bandage beyond. The tips of the fingers and toes should always be left exposed to inspection. Patients with atheromatous vessels, heart disease and diabetes are especially prone to have gangrene following fractures. Every effort should be made to preserve their circulation. When gangrene appears, the surgeon should determine its cause, and when this is not removable the further treatment must depend upon the absence or presence of infection. If infection is present amputation is called for. *Fat embolism* and *blood embolism* have been discussed.

For *infection* and *inflammation* see pages 228 and 237.

Muscular spasm should be corrected by removing the mechanical irritation to the nerve trunk. When nothing further can be done constant traction must be depended upon to overcome it. *Osteitis* is discussed elsewhere. *Necrosis* of bone is a common complication in infected compound fractures. Loose spicules of dead bone should be removed. When a bone surface is seen at the bottom of the wound to be white and devitalized, the surgeon has no guide but experience. Sometimes such an appearance signifies but a superficial area of anemia which will ultimately become covered by periosteum. If the area is extensive and involves more than a third of the circumference of the bone, necrosis and exfoliation may be looked for. In this case the surgeon may await the natural process of exfoliation or he may save time for the patient by chiseling away the dead bone (see Operations on Bones and Joints, page 688).

Stiffness of joints following injury or prolonged immobilization is most pronounced in old and atheromatous patients. To prevent this, joints should be liberated from confinement as early as possible. Active and passive motion should be instituted as soon as the other conditions will permit. Massage is a valuable help. *Atrophy of the limb* occurs in all fractures involving these members, chiefly because of disuse. For this reason a plaster cast which at first was snug may become too loose to be efficient. The after-treatment of this condition is massage and use of the limb. *Pain*, referred to the distribution of a nerve or about the seat of fracture, may be due to the involvement of a nerve in callus or inflammatory exudate or to some other pressure-producing condition, and require that the nerve shall be cut down upon and relieved. *Paralysis* of muscles or of sensation may require the same treatment as pain. These accidents are most prone to happen to the nerves about the humerus.

Excessive callus usually results from too much motion at the fracture. The remedy is perfect immobilization. Care should be taken that this condition is not mistaken for sarcoma and the patient visited with the direful consequences of both defective diagnosis and treatment. This accident to patients has occurred. For the treatment of *sarcoma* of bone, developing in fractures, see Tumors, page 323. *Arthritis* and *tendosynovitis* are discussed elsewhere. *Shortening* of the limb, resulting from overriding or loss of substance, is discussed elsewhere. *Surgical emphysema*, found associated with fractures which have caused wounds of mucous membrane or skin in some part participating in the respiratory movements, is cured by nature; the air is gradually absorbed from the connective-tissue spaces. If the pressure becomes extreme, incisions into the skin will relieve it.

Hypostatic congestion of the lungs is a not uncommon complication of fractures found in *old persons*. It should be watched for in recumbent

patients, and, upon its first appearance, the patient should be allowed to sit up. The treatment of the patient and the saving of his life should take precedence over the treatment of the fracture. In such cases the fracture should be treated in such a way that the patient may not be required to lie all the time in the recumbent position. It is better surgery to be satisfied with a less perfect local result, and preserve the patient, than to allow technical zeal to strive for a perfect cure of the fracture at the cost of the patient's life. These old people also are prone to suffer from *bed sores*, which must be guarded against and treated according to the rules already laid down (Bed-sores, page 313). No matter what bone is broken, it is unwise to so immobilize an old person that the skin of the posterior parts of the body cannot be inspected. The patient should be so treated that he can either be turned upon one side or lifted up so that the skin of the back may have a daily rub with alcohol and be kept well powdered. Inhibition of the functions of the *excretory organs*, *suppression of urine* and *retention of urine* due to *senility* may call for treatment. These conditions are to be met by attention to everything that will conduce to better vitality, fresh air, cleansing the gastrointestinal tract, simple nourishing food, massage and stimulation when necessary to whip up a temporary flagging of important innervation. When catheterization is resorted to it should be done with all the care that would be bestowed upon a more hopeful case. Under conscientious treatment old people recover from desperate conditions. Distension of the bladder should be watched for, and the surgeon spared the humiliation of having a paralyzed bladder to deal with.

Delirium tremens, common among persons who have habitually damaged the integrity of their glandular organs by drinking *alcohol*, comes on when such persons sustain a shock to their nervous system by such an accident as fracture and which compells them to remain recumbent in bed. The first step in the treatment consists in discontinuing the ingestion of alcohol. The next important thing is a thorough cleansing of the gastrointestinal tract. This should be done by laxatives and enemas. Free and speedy catharsis should be secured. If there is chronic gastritis, and commonly there is, lavage is indicated. Having removed as much as possible of the fermenting, toxin-producing material from the bowel, the nourishment of the patient is the next important consideration. Peptonized milk, raw eggs, whey, albumin water, dextrinized gruel and a little fruit juice are the essentials. Meat and other solid foods are objectionable. If much catarrhal gastritis is present lavage should be practised daily and all food should be given with pepsin or peptonized. Fresh air is just as essential for these patients as it is for the tuberculous. Plenty of water and a daily movement of the bowels are of value. There is no drug or combination of drugs that can be regarded as a remedy for delirium tremens.

If, despite the above hygienic treatment, tremor and delirium continue, sedative drugs are called for. Bromides and chloral seem to be of the most service. Three-tenths of a gram (5 grains) each of the bromide of sodium, potassium, and ammonium, combined with 1 Gm. (15 grains) of chloral hydrate, may be given 3 or 4 times daily. In severe delirium a hypodermic injection of 0.015 Gm. (¼ grain) morphin and 0.0005 Gm. (1/120 grain) atropin may have to be given; or the patient may require to be restrained with a straight jacket. If these patients seem not to be doing well an infusion of saline or glucose solution (500 c.c.) into a vein in the arm can be depended upon to produce a change for the better. I first described this procedure for the treatment of the later stage of delirium tremens in 1901 (J. P. Warbasse: The Treatment of Delirium Tremens by the Intra-

venous Infusion of Saline Solution, Medical News, March, 1901; Transactions New York State Med. Soc., 1901); and since that time I have seen cases, which might be spoken of as moribund, recover under this treatment. A patient whose temperature has rapidly and steadily arisen to 41.5°C. (106.5°F.), who is in a state of coma, whose skin is cyanotic, whose pulse is scarcely perceptible, and whose face is bathed in perspiration, need not be despaired of if an infusion can be given. I have never witnessed more striking benefits, not even in hemorrhage, from this therapeutic measure than in delirium tremens. If necessary the infusion may be repeated every day. Glucose, instead of salt, is to be preferred in cases with damaged kidneys.

Lumbar puncture, to relieve the increased cerebrospinal pressure is advantageous. In some cases the pressure is so high that as much as 100 c.c. may be withdrawn. There is probably an advantage in injecting 15 or 20 c.c. of salt solution after the pressure has been relieved. In the meantime the hygienic measures to minimize auto-intoxication should be practised.

A final duty devolves upon the surgeon after the patient is well and about to be discharged from his care; and that is to inform him of the narrow escape from death which he has had, to tell him frankly that alcohol was the cause of the precarious condition into which he fell, and to advise him against its use. This is a part of the treatment of delirium tremens, and the surgeon's whole duty is not done until he administers it.

Traumatic delirium or *delirium nervosum*, the condition of nervous excitement often found associated with fractures, requires the same treatment as neurasthenia. *Crutch paralysis*, from the pressure of crutches upon the nerves in the axilla should be watched for and when first observed should be met by discontinuing the axillary pressure.

Faulty or *vicious union* results from the absence of treatment of fractures, or when consolidation takes place in the fragments not in normal opposition. It requires treatment when it impairs the usefulness or symmetry of a limb, and when it gives rise to symptoms of pressure upon nerves or vessels. If the deformity is but slight, the impairment of function inconsiderable and the patient satisfied with the result, no treatment need be urged. Most fractures of long bones heal with more or less faulty union (J. P. Warbasse: The Treatment of Fractures, Jour. Amer. Med. Assoc., vol. 52, March 13, 1909, p. 857). In the more extreme cases of faulty union the bone should be refractured, the deformity corrected, and the treatment of the fracture begun anew. Within the first few weeks the refracture of a bone with angular deformity is a simple matter; but when the fracture is old, or situated near a joint, or has healed with overriding, great care is required. The bone may be broken by simple manual force. Often it is best to bind splints firmly to the limb above and below the point where it is desired to make the break, in order to localize the strain. The instrument known as the osteoclast may be used with advantage in some cases. The most exact treatment is by osteotomy. This may be done by a subcutaneous operation in the more simple cases, or by the open method in cases with overriding of the fragments. It sometimes becomes necessary to resect a portion of the bone before a perfect reposition can be made. Often in operating upon the humerus or femur, mortising or some other method of direct fixation is necessary.

Delayed union is a retardation of the reparative process in which the bone is united by unossified or imperfectly ossified connective tissue or callus. It is caused by imperfect retention, too early mobilization, overriding, and separation of the fragments by intervening tissues. Inflammation in com-

pound fractures is a common cause of delayed union. It is more rarely due to certain constitutional disturbances, such as cause slow production of plastic material at the seat of the fracture or slow ossification of the callus from poverty of lime salts. The treatment, therefore, consists first in removing any discoverable cause. Local nourishment should be improved by increasing the blood-supply and by improving the patient's general condition. Inducing local hyperemia is of much help in these cases. It may be secured by means of suction cups or by elastic constriction (page 229). Hyperemia may be secured by hammering the region of the fractures each day for twenty minutes with a padded mallet or a hammer made of paraffin or wax. Good results are also secured by driving into the bone-ends pegs of bone or ivory which are left *in situ*. The bones may be bored or punctured in several places without leaving in any pegs. Another method of arousing hyperemia is to break asunder forcibly the fibrous attachment by flexion and rotation, followed by rubbing together the bone-ends. This should be done under general anesthesia. If necessary the operation should be repeated until pain, tenderness and swelling testify to the presence of local reaction. Immobilization should then be applied. Union has been secured in some of these cases by producing impaction. Bier used with much success the injection of blood at the seat of the fracture. It should be injected between the bone-ends and beneath the periosteum so that the whole blood-mass is continuous. The patient's own blood is to be preferred. Six months is not too long a time to give to securing consolidation. Time can often be saved in these cases by doing an open operation, freshening the ends of the bones, applying direct fixation and putting up the bone as a recent fracture.

Fibrous or *ligamentous union* consists in the connection of the bone-ends by means of unossified fibrous connective tissue, which permits more or less motion between the fragments. It is produced by any of the causes which produce delayed union. Its most common cause is the interposition of soft tissue such as muscle or fascia, or loose bone fragment. It is delayed union without a tendency to ossification. The treatment, therefore, is the same as that for delayed union. In fibrous union open operation should be more freely resorted to.

If the treatment for delayed union does not seem to promise well or if much time has been given already to treatment, no further time should be expended upon tentative measures. The bone should be cut down upon, the intervening soft tissue should be removed, the fragments freshened by sawing or cutting off the ends, and the freshened bone surfaces brought together. It is often found that the bone near the fracture has become atrophied and porous. When this condition exists the periosteum should be stripped away from the bone, but left attached to the surrounding tissues; the most softened part of the degenerated bone should be cut away. It sometimes occurs that there is so great a destruction of bone that a considerable space is left, which may require to be filled by an osteoplastic operation or by the transplantation of bone. The implantation of a bone graft is the most effective treatment. Such a graft is best taken from the sound tibia. A groove may be cut in each fragment, and the graft placed in it as an inlay. Or the graft may be cut in the form of a peg, and each end driven into a drill hole in the end of each fragment.

In preference to removing atrophied bone it is often best to stimulate it by making multiple longitudinal incisions into it. Finally, there are cases of old fibrous union in which the usefulness of the part is not materially impaired. These cases need no treatment.

The constant rubbing together of the fibrous covered ends of the bones

sometimes results in the formation of a bursal sac between the fragments. There a new joint is formed, in which the connective tissue representing the unossified callus, forms the capsular ligament. If operative treatment is indicated, the new joint-sac must be removed, and the treatment proceeded with upon the lines laid down above.

Non-union is a comparative rare condition in which little or no reparative action has taken place, and should not be confused with delayed union and with fibrous union. The bone-ends, not being connected by new formed tissue, lie free in the soft tissues. The treatment, therefore, is the same as that for delayed or ligamentous union, followed if necessary by open operation, and fixation of the bone ends.

INTRA-UTERINE FRACTURES

Intra-uterine fractures, occurring in the child *in utero*, have usually united at birth and require treatment for vicious union (page 527). If union has not taken place, they become fractures in the newborn.

FRACTURES IN THE NEWBORN

These fractures are not difficult to manage if handled with care and patience. The musculature of the infant is so poorly developed that it

FIG. 385.—DOUBLE RIGHT ANGLE SPLINT FOR TREATMENT OF FRACTURE OF THE HUMERUS IN THE NEWBORN.

FIG. 385*a*.—DOUBLE RECTANGULAR SPLINT AND POSITION OF ARMS WHEN APPLIED IN FRACTURE OF THE HUMERUS. (*After Spitzy.*)

does not tend to produce displacements, and growth and regeneration are so active that repair goes on rapidly. Union takes about four weeks.

Fracture of the humerus is best treated in the double right angular splint (Fig. 385). Such a splint may be made of wire, covered with a plaster-of-Paris, of heavy paper board, metal or wood. Such a splint, well padded with gauze, is placed across the child's back, the two arms of the splint being applied to the forearms. It is fixed in place by a flannel bandage (Fig. 385*a*). This meets the abduction of the upper fragment, and immobilizes the arms.

Fracture of the *humerus* may be treated by placing a well-powdered layer of gauze between the arm and the thorax and bandaging the arm to the latter. The forearm may or may not be confined by being bandaged flexed across the front of the chest, as the conditions indicate.

Fracture of the clavicle in the newborn is apt to heal with deformity unless the shoulder can be held back and immobilized. Spitzy (W. F. Campbell: Medical Times, Sept., 1915, page 291) makes an inverted T-shaped splint of paper board which lies on the back, the two arms being applied to the forearms of the child. Adhesive plaster straps fix it to the shoulders, and bandages to the arms (Fig. 386).

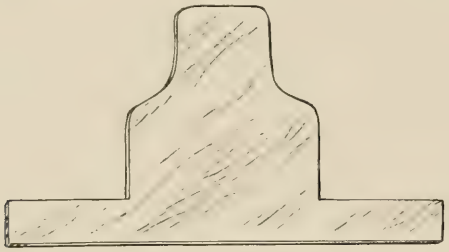


FIG. 386.—DOUBLE-ARMED SPLINT FOR TREATMENT OF FRACTURE OF THE CLAVICLE IN THE NEWBORN.

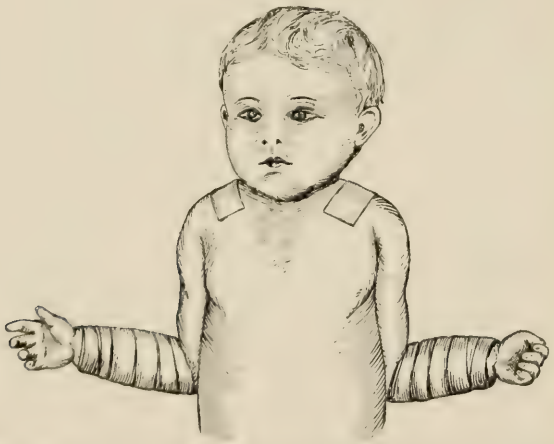


FIG. 386*a*.—THE DOUBLE-ARMED SPLINT, APPLIED IN FRACTURE OF THE CLAVICLE (*After Spitzy.*)

It may be treated in much the same way as fracture of the humerus: a thicker pad is placed in the axilla, the arm is bound to the side of the chest, and the flexed forearm fixed anteriorly.

Fracture of the femur may be treated by an anterior splint and plaster-of-Paris fixation. The splint should be of malleable iron 3 mm. (⅛ inch) thick and 2.5 cm. (1 inch) wide, consisting of two strips, united above, reaching from the middle of the sternum to the toes, and bent to conform to the flexed hips, knees and ankles (Fig. 387). It should be well padded and incorporated in plaster-of-Paris about the chest, knees and legs, but omitted from the pelvis and upper thighs for the sake of cleanliness.

Fracture of the femur may also be treated by using the trunk as a splint. To do this, the skin should be well powdered, particularly in the groin; the

thigh is then strongly flexed so that it lies upon the abdomen; an adhesive strip is then passed around the loins, across the abdomen and the posterior aspect of the strongly flexed thigh, holding the latter against the body and at the same time acting as a splint (Fig. 388). To avoid the irritation to the skin caused by the adhesive plaster a bandage may be applied first and the plaster put on the bandage. This has the disadvantage that the bandage is apt to become wet and cause more irritation that well-powdered plaster

FIG. 387.—BENT IRON SPLINT TO BE PADDED AND HELD WITH BANDAGE FOR TREATMENT OF FRACTURE OF THE FEMUR IN THE NEWBORN. (*After Spitzy.*)

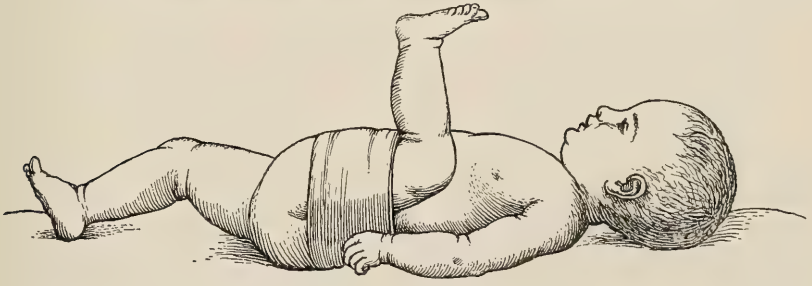


FIG. 388.—THIGH BANDAGED TO TRUNK IN TREATMENT OF FRACTURE OF FEMUR OF THE NEWBORN.

does. The dressing should be changed every week or two, to inspect the skin and clean and repowder the groin. If the latter becomes irritated a little gauze with abundant *baby powder* (zinc stearate, 3; lycopodium, 2; boric acid, 1) should be placed in the groin. A good plan is to apply first a well-powdered flannel bandage and then over that a wider adhesive strap so that it extends beyond the edges of the bandage and keeps the latter from becoming soiled. This fracture may also be treated by vertical extension or in the double side splint (see Fractures of Femur).

Fractures of the leg and forearm are best treated in light moulded splints of plaster-of-Paris, water glass or starch, incorporating a thin strip of pasteboard.

SPECIAL FRACTURES

Fractures of The Skull

Simple linear fractures of the vault of the skull without symptoms of brain compression require no especial treatment aside from keeping the patient quiet for two or three weeks. These fractures are so commonly complicated by fractures of the base that this precaution is of much importance.

Simple linear fractures of the vault of the skull with symptoms of brain compression require the same treatment as the above fractures, excepting with the addition of treatment of the brain compressing factors. These are discussed more fully under Brain Injuries (Vol. II). Briefly, a slight degree of brain pressure due to bloody and serous exudate, is often associated with such fractures, and, because of its slightness and tendency to subside, requires only rest and quiet of the patient. If the pressure is something more than the inevitable bloody and serous effusion that accompanies all fractures, but shows a tendency to increase, to cause decided slowing of the pulse and stupor, then the fracture should be exposed, the skull should be opened, and the pressure-producing factor dealt with. Clot should be removed, and the bleeding vessel, commonly a branch of the middle meningeal, sought.

Simple depressed fractures of the skull with or without symptoms of brain compression or irritation, should be treated by elevation of the depressed bone away from the brain. Very commonly in such fractures, after the primary symptoms of brain contusion have subsided the depression gives no discernible symptoms. This is often the case in the frontal region. But elevation of the depressed bone is called for because of the great danger of later disturbances. It is in such cases that epilepsy often appears long after the injury. The diagnosis in these cases is not always easy, contusion and hematoma of the scalp sometimes confusing the tactile sense; but rather than let a depression go uncorrected, it is better to be on the safe side, if there is a doubt, and clear up the diagnosis by incision. Hematoma and contusion cause a feeling of softness and depression, separated from the rest of the hard scalp by a sharp margin of harder scalp, which is often mistaken by the inexperienced for an edge of bone. It should be borne in mind that contusion and hematoma of the scalp not infrequently complicate as well as simulate depressed fracture.

A depression being discovered, it is best elevated by a strong periosteal elevator acting as a lever. In order to insert the lever beneath the bone an opening must be made by the trephine, applied to the line of fracture, or by picking out a loose bit of bone. The lever should be engaged beneath the inner table and not in the diploë. It often happens that the depressed fragment is caught beneath the edge of the skull. In such cases the overhanging edge may be cut away and the bone elevated (Fig. 389).

If elevation by this means is not possible because of double or "gutter depression" it should not be persisted in but the bone on either side of the line of fracture should be cut away by bone-cutting forceps. This is best done by following the line of fracture with a pair of skull-cutting rongeur forceps. The bone being freed at the depressed edge, it is easy to elevate it with lever or forceps. This operation, on the whole, is preferable to prying up the bone without cutting it free, because in the latter case there is danger of leaving spicules of bone impinging upon the meninges or brain.

The **gutter fracture** of the skull is most difficult to handle. The most satisfactory method of procedure is to make an opening through the skull at one end of a bank of the gutter, where it joins the undepressed bone,

insert the skull-cutting rongeur, and follow the line of fracture between the depressed and undepressed bone. An elevator may then be inserted at the bottom of the gutter and elevation accomplished (Fig. 390). Care should be taken not to depress one side while the other is being elevated. Complete

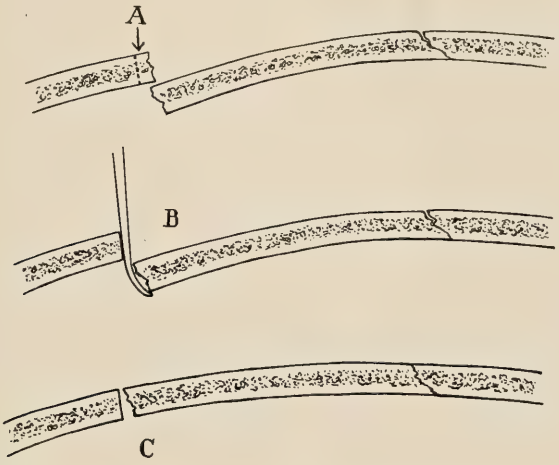


FIG. 389.—DEPRESSED FRACTURE OF SKULL SHOWING LINE FOR CUTTING AWAY OVERHANGING SHELF OF SKULL WHICH PREVENTS ELEVATION OF DEPRESSED FRACTURE.
A, Bone to be cut away; *B*, fragment about to be elevated; *C*, result after elevation.

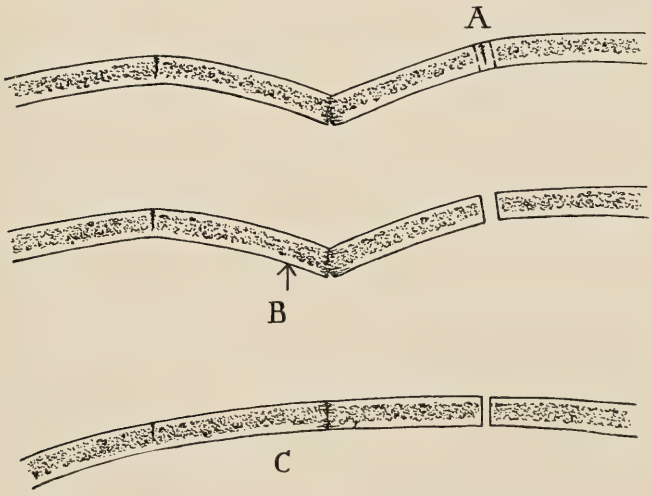


FIG. 390.—ELEVATION OF GUTTER FRACTURE OF SKULL.
A, Segment of bone to be removed by rongeur forceps; *B*, point for application of prying force; *C*, result after elevation.

depression, such as is caused by a blow with a hammer, is elevated by first making a small trephine opening in sound bone at the edge of the fracture, through which the elevator may be passed to pry up the bone. Often more than one trephine opening must be made.

The periosteum in such operations should be carefully preserved. The operation should be done with aseptic care because it may be desirable to

replace loose pieces of bone. The dura should be spared injury. If it is found torn, it should be sutured with fine chromic catgut. If there is bleeding from the pia mater, the wound in the dura should be packed to control it. A further description of operations upon the skull will be found under that heading and in the chapter on osteoplastic operations.

Compound Fractures of the Skull.—The general treatment is the same as for compound fractures in other bones (see Compound Fractures, page 518). The scalp should be shaved for a distance of at least 5 cm. (2 inches) around the wound. If the wound is large the whole scalp should be shaved. The scalp and the wound should be cleansed. Foreign matter should be removed by irrigation, or with forceps. Ragged tissue should be cut away. Torn periosteum should be replaced. A soiled wound should be treated with iodin or chlorin. The wound should be sutured, drainage being provided in a dependent position by a very small tube or a few strands of silkworm-gut. If the wound has not been much soiled or contused, drainage may be dispensed with. If parts uncovered by hair are involved, especial pains to secure nice apposition of the skin should be taken. The patient should be kept quietly in bed.

Compound fractures of the skull without depression or symptoms of brain injury are treated by the rules just given. The patient should be kept quietly in bed for at least a week.

Compound fractures with symptoms of brain compression should receive the same treatment as simple fractures with the same complications, excepting that in exposing and opening the skull the operation in the compound fracture should be done through the wound present, unless there are localizing symptoms pointing to some other region. If the wound has been seriously infected, it should be dried and treated with chlorin or iodin before opening the skull.

Compound depressed fractures of the skull should receive the treatment laid down for compound fractures in general and for simple depressed fractures. See above. The wound should be cleansed, enlarged if necessary the depressed bone elevated, and the wound closed. Usually drainage should be provided for a few days.

The General Treatment of Fracture of the Base of the Skull.—These fractures are much more common injuries than was formerly supposed. Usually they are compound because of communication through the auditory canal and the ruptured tympanum, through the nose in fractures of the anterior fossa, and through the roof of the pharynx. The dangers are from infection through the ears, nose or mouth, producing meningitis; and from exudate and hemorrhage, causing brain pressure. Efforts to prevent infection should be made. The mouth should be kept clean. If there is rupture of the tympanum and a discharge of bloody cerebral fluid, the ear should be guarded against infection. It is customary to irrigate the external auditory canal with antiseptic solution and lightly close it with sterile gauze. Cases in which this is practised seem to do no better than those in which the ears are not treated. There may or may not be infective material on the outer surface of the tympanum, usually there is. If present it is doubtful if it can be washed away by irrigation; while irrigation may drive it through the wound of the tympanum. The important matter is that the cerebrospinal fluid, leaking out through the fracture into the middle ear and thence through the ruptured tympanum, shall have free escape. If the current is continuously outward, infection and meningitis need not be feared. But aspiration of fluid, that has once passed through the tympanum, back into the middle ear again is the great danger. This accident

is caused by changes of the position of the patient, turning the head with the injured side up, and by the outer canal becoming occluded by dried discharges. Unless irrigation is done very carefully there are positive dangers in it, and it is possible for an occlusive plugging of the ears to be a decided menace.

For immobilizing the head a posterior splint of plaster-of-Paris is used. This involves the head, neck and back of thorax, and is supplemented by plaster bandages encasing the forehead, neck, shoulders and chest. The object of this splint is to immobilize the head and neck so that muscular action can not cause any motion between the fragments of the broken bone and to inhibit the motions of the cerebrospinal fluid. In applying this cuirasse, if the head is slightly turned toward the injured side, the best provision for drainage is secured (Fig. 391). Enough sedative should be given to keep the patient quiet. This is important. The bowels should be moved by enema. The diet should be simple, soft foods such as soups, eggs and milk.

If there is no rupture of the tympanum, but oozing of bloody cerebral fluid from the nose or roof of the pharynx, the head need not be rotated, but the necessity for quiet is just as great. There is the same indication for immobilization as when the ear is involved. It is doubtful if any irrigation, cleansing or occlusive plugging can be of value here. That there should be free exit for discharges is the important thing.

Immobilization seems called for especially when the fracture is a long one; when there is fracture of the vault combined with fracture of the base; or when the fracture of the base involves both sides. Theoretically immobilization of the head seems valuable, but in practice I have never been able to convince myself that it gave any better results than no immobilization. There is always the danger that the muscles acting to move the head may operate upon one side of the fracture and the resistance of the cuirasse may act upon the other, and thus produce more mobility than would be the case if the head were left free. On the whole, the hypodermic use of morphin may be relied upon to secure quiet.

FIG. 391.—PLASTER-OF-PARIS CUIRASSE TO IMMOBILIZE HEAD AND NECK IN TREATMENT OF FRACTURES OF THE BASE OF THE SKULL AND CERVICAL VERTEBRÆ.

When the wound which made the fracture compound has healed, and cerebral fluid ceases to flow the greatest danger has passed, but it not uncommonly happens that infection has already passed in and is working its way to the meninges. These patients should be kept quiet until their symptoms have all disappeared. Usually, if there has not been much hemorrhage or exudate, this is a matter of about three weeks. The fracture may be regarded as healed in four or five weeks.

Simple fractures of the base require quiet, and rest in bed for at least three weeks, or until symptoms have subsided.

If symptoms of increased intracranial pressure are present, and if these symptoms are increasing, a subtemporal operation for decompression should

be done. The sooner this operation is done the better. Local injury also demands operation.

The *operative treatment* of basilar fractures has given excellent results. It aims to provide drainage for the possibly infected subdural space and to relieve pressure. As it cannot be determined whether or not infection has entered until the signs of meningitis appear, some surgeons have advocated operation in all cases. The skull should be opened as near the fracture as possible. Usually this is best accomplished by trephining in the lower part of the temporal fossa or performing the typical operation for decompression (see Operations on the Skull, Vol. II). The dura mater should be incised so as to give free drainage. A small drain should be inserted and the skin sutured around it. Drainage may be continued for from four days to two weeks, or as it seems indicated. This operation not only provides drainage of the cerebrospinal fluid, but in case a blood-vessel has been ruptured,

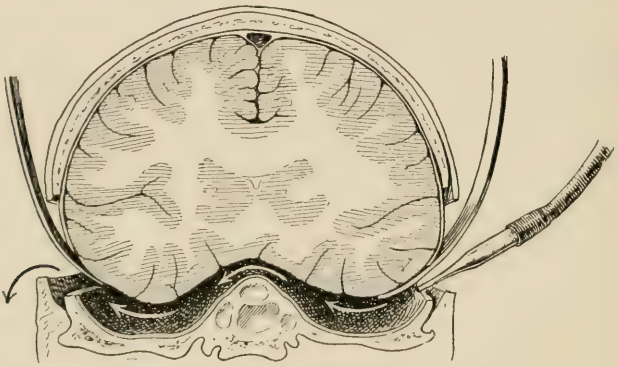


FIG. 392.—METHOD OF WASHING OUT BLOOD AND CLOTS FROM THE BASE OF THE BRAIN THROUGH SUBTEMPORAL OPENINGS.

Method of Elsberg.

in case of pressure from general bloody oozing, or in case of edematous pressure, all of which are not uncommon in this injury, the important step for cure has been taken. As the majority of cases of fracture of the base recover, often even without diagnosis, it can not be said how strongly this operation should be urged. It can only be said that the well-equipped surgeon may properly adopt it as a routine measure. In cases with increasing pressure signs it is imperatively demanded. There is a train of central nervous disturbanc which often follow fracture of the base, and which may be prevented by the operation.

Lumbar puncture has often relieved the symptoms of pressure, sometimes withdrawing sterile fluid and sometimes infected fluid. It is because of this also that trephining near the fracture seems a more reasonable procedure. It should be borne in mind that the force which causes the fracture may also produce other injuries of the brain, demanding operation. Often clots are found between the dura and the skull; and the removal of these and drainage of the extradural space are important.

In cases with much pressure, indicating extensive clot at the base of the brain, the blood may be washed out by making a low temporal opening on either side and irrigating through-and-through with warm salt solution. C. A. Elsberg (Surg. Gyn. and Obst., Aug., 1916) has advocated this method. By lifting up the brain with a spatula on either side, the irrigation is facilitated (Fig. 392). Usually such clot is found only on one side and through-and-through drainage is impossible.

Fractures of the base of the skull without compression symptoms are treated upon the lines laid down above for the general treatment of fractures of the base: quiet of the patient secured by morphin if necessary, unobstructed drainage of cerebral fluid if the fracture is compound, simple nourishing diet, and a daily evacuation of the bowels.

Fractures of the base of the skull with symptoms of brain compression are common. The symptoms of compression may be slight but they may be detected by careful examination. Usually the compression symptoms are due to the exudation peculiar to all fractures, and slight because of the almost complete immobilization. The exudation is usually enough to produce some cerebral-compression symptoms which have commonly been put down under the vague and misleading name of "concussion." The exudate and blood are absorbed in two or three weeks; and the only treatment necessary is that described for fractures of the base in general. In some cases the pressure is more than enough to produce slight irritation of the base of the brain; there may be serious signs of compression. The treatment of this condition I described in 1898, along with a report of cases treated by operation (J. P. Warbasse: The Operative Relief of Brain Compression from Intracranial Hemorrhage, Brooklyn Medical Journal, Jan., 1899). If the pressure continues to increase, the pulse becoming progressively slower, or if the pressure is producing coma and other symptoms indicative of serious interference with the brain functions, then it should be relieved by trephining somewhere along the lower part of the vault of the cranium, the site of operation being guided by the localizing symptoms (see Operations on the Skull and Brain). It cannot be expected that the operation will always disclose a clot that can be removed. But the liberation of bloody cerebrospinal fluid and serum can be accomplished; and this, as already shown, may be sufficient to turn the course of the case toward recovery.

Fractures of the base of the skull with meningeal infection require the treatment laid down for fractures of the base plus the treatment of meningitis (see Meningitis, Vol. II).

Fractures of the vault and base of the skull are common. Many fractures of the vault run down into the base. Each requires the treatment already described for the separate varieties of fracture.

Punctured fractures through the orbit are serious wounds. Treatment must vary with the complications present. If the eyeball is destroyed, immediate enucleation will give better drainage. If the wounding instrument has passed to one side of the eyeball and there is much hemorrhage into the orbit, a strip of gauze passed back along the wound may be expected to control the bleeding and serve for drainage. If there is evidence of intracranial hemorrhage it may be reached by trephining laterally in the temporal fossa opposite the anterior lacerated foramen. I have had such a case, following a puncture with an umbrella, recover without operation after hemorrhage had reduced the pulse rate from 74 to 50 per minute. In the majority of these cases the external wound of the eye should be treated, the patient kept at rest, and watched for later symptoms of infection or abscess of the brain.

Fractures of Vertebræ

The treatment of fractures of the vertebræ is directed almost entirely in the interest of the spinal cord and the nerves. Fractures of the various processes, if there is no nerve injury, require quiet until union has taken place. If there is displacement, manipulation should correct it. In fractures

of the bodies or laminæ, if there is no injury to the cord, rest in bed on a water mattress or immobilization in a plaster jacket are required.

The more serious fractures, in which there is injury to the cord, demand special consideration. First it must be determined whether the cord is completely severed or partially divided, whether the injury is a wound of the cord or compression and whether the compression is due to displacement of bone or to hemorrhage. If the cord is completely divided, as determined by the peripheral nerve examination, its union can not be hoped for; and it remains to make the patient comfortable, correct deformity by extension, keep the patient on a water bed and give the necessary attentions to the paralyzed organs. Operations upon the cord in these cases have not resulted in the restoration of function. Displacement of bone, which has partly severed the cord and still compresses the rest of the cord, should be corrected. This should be done by extension and manipulation, but if not accomplished by these means then by operation. If there is no displacement of bone sufficient to produce cord injury, but evidences of pressure are present, hemorrhage may be assumed to be responsible for the symptoms (see Surgery of the Cord).

Fractures with compression below the first lumbar vertebra, if the compression cannot be corrected by extension may be operated upon with hope of good results. This is because the compression here affects the cauda equina which is not so susceptible to irreparable damage as the cord. Another class of fractures with compressing displacement which should be treated by operation are fractures of the vertebral arch, made up of the laminæ connected by the spinous process. Operation here is indicated because this part of the bone is easily accessible; its removal is simple and without danger; and it forms the part of the vertebral canal which can be reached without disturbing the cord. Very commonly depressed, distorted and tilted pieces of lamina may be removed with advantage. This condition is so commonly present that operation to expose the lamina is indicated upon the slightest possibility of its presence. In all fractures of the spine the removal of fragments of bone which encroach upon the spinal canal is a most important part of the treatment.

In most cases of fracture of the spine, whether cord injury is present or not, the most satisfactory means of immobilization is in a plaster-of-Paris jacket. This is best applied with the patient in a hammock of muslin, the muslin being included in the jacket and then cut off above and below. A cotton undershirt is put on and the patient laid in the hammock. If the fracture was sustained by a fall upon the back or other injury which produced hyperextension, then the patient should lie in the hammock upon his back, thus producing slight flexion of the spine. In other fractures the best position is usually secured by having the patient lie upon his abdomen, giving slight extension of the spine. These same corrective positions may be secured by having the patient lie upon two tables which are sufficiently separated to permit the desired bending of the spine (see Treatment of Tuberculosis of the Spine, Vol. II). Fractures in the upper dorsal and cervical spine are treated in plaster as applied in tuberculosis of those regions. The question as to whether extension or flexion of the spine is desirable in the treatment of a given case of fracture may be determined by the *x*-ray examination.

In the treatment of fractures of the vertebræ, diagnostic skill should first determine the nature of the injury. The neurologic and *x*-ray examinations are of great importance. Hemorrhage into the spinal canal and dislocation and laceration of the cord without fracture are conditions to be differentiated. After the treatment has begun, it will commonly be observed that there is

improvement as the exudate and hemorrhagic effusion incident to the injury are absorbed. If there is paralysis, the condition of the paralyzed parts will demand the most attention. The skin must be kept clean and healthy. In no class of injuries is it more important to prevent the formation of bed sores. Hope of further improvement should always be indulged (see Spine and Cord, Vol. II).

Fractures of the Nasal Bones

As a result of blows upon the nose the nasal bones may be broken and depressed and the septum of the nose fractured. The treatment of fractures of the nose should be preceded by an examination of both nasal cavities with the aid of a speculum and a good light. Even though there is no deformity, the septum should be examined for hematoma, and, if found, it should be opened after cleansing the nose with boric acid solution. Such hematomata if left are prone to suppurate and cause necrosis of the septum. Hemorrhage from a wound of the septum is controlled by packing the nostril with iodoform gauze. In all cases of fracture of the nose the mucous membrane should be kept cleansed with boracic solution.

Fig. 393.—Fracture of Nose Treated by Stiff Rubber Tubing to Support a Packing of Gauze which is Introduced above and below it.

If there is depression of nasal bone it should be elevated into position. The operation should be done under cocain or novocain anesthesia of the mucous membrane, or, in very sensitive persons, under the first stage of general anesthesia. Otherwise it is an extremely painful procedure. For elevating the depressed bone, any strong round-ended instrument may be used—such as a periosteal elevator, small urethral sound, round-ended scissors, or endoscope. When the bone is lifted into place, it may remain in position. If it does, no splint is required. The patient should be warned against touching it or blowing his nose. If there is a tendency to recurrence of displacement, the bone should be supported from below. Many devices have been contrived for this purpose. Nothing is more satisfactory than a piece of stiff rubber tubing passed into the nostril, through which the patient may breathe, and a packing of iodized gauze above it, inserted tightly enough to hold up the bone (Fig. 393). This dressing should all be removed every two or three days and the nostril irrigated with mild alkaline solution (see Nose, Cleansing of, Vol. II). Such a support is required for not longer than two or three weeks. In four weeks the bone has united.

Lateral displacements are best corrected by upward pressure inside the nostril at the same time that lateral pressure is made on the outside. If there is a tendency to recurrence, continuous lateral pressure must be made. This may often be accomplished by means of a pad and an adhesive strap; but in some cases something stronger than this is required Many splints for this purpose have been devised. One of the most practical consists of a plate held to the forehead by adhesive plaster and a bandage, from which plate a nose-piece, having pads on either side mounted upon screws, projects (Fig. 394). These screws may be tightened down on whichever side pressure is required, being properly padded and fixed by adhesive strips. Only a few

days of such pressure are required before the bone becomes agglutinated in place.

Rarely will a nasal fracture be found that cannot be controlled by the above methods. Such fractures may be treated by transfixing the nose by a heavy needle and applying pressure by winding a rubber elastic across properly applied pads of gauze (Fig. 395). The operation should be done with aseptic care, the nostrils cleansed and the gauze pads powdered.

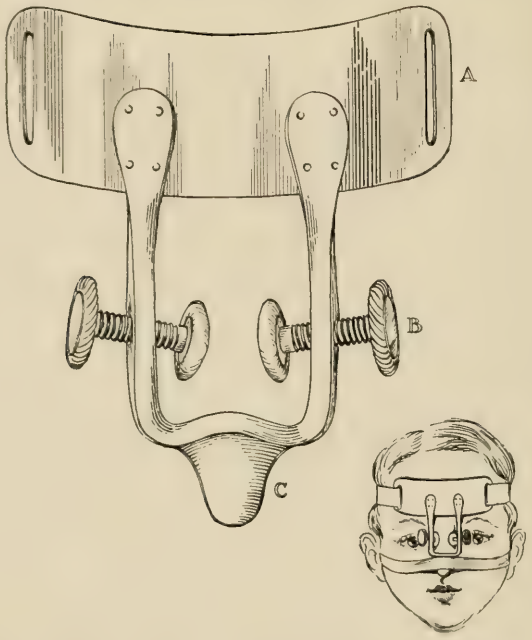


FIG. 394.—SPLINT FOR MAKING LATERAL PRESSURE UPON THE NOSE IN FRACTURES WITH LATERAL DISPLACEMENT.

A, Forehead plate, held by band about the head; *B*, screws, pressing a pad against the sides of the nose; *C*, end piece to be held down upon nose by adhesive strip passing to cheeks.

Fractures of the septum and detachment of the cartilage should be looked for in connection with fractures of the nasal bones. Usually the treatment which corrects the external displacement also corrects the septal displacement. If a tendency to deformity persists it may be corrected by packing the nostrils with a rubber tube and gauze. Sometimes it is necessary to grasp the septum with forceps, one blade being passed in each nostril, and make forcible correction.

FRACTURES OF THE MALAR BONE AND ZYGOMA

Fracture of the malar bone near the superior maxilla requires no splint and usually remains in good position. The common fracture is a driving in of the zygomatic arch against the temporal muscle. Usually this is not sufficient to interfere with the flexion of the lower jaw and when union has taken place there is still some depression. The bone may be grasped with strong tenaculum forceps through the skin and drawn back in place (Fig. 396). Rarely can the deformity be corrected without some such procedure. Often the depression must be operated upon later for cosmetic reasons if the

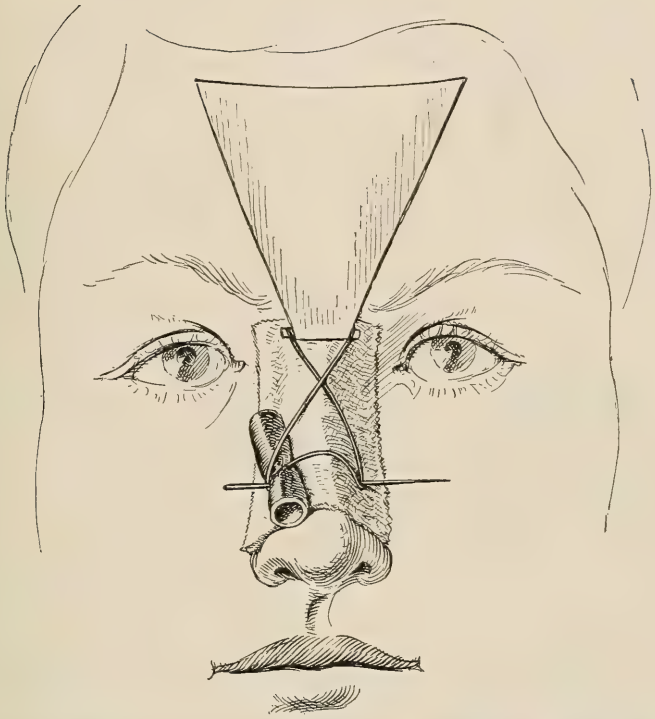


FIG. 395.—FRACTURE OF NASAL BONE TREATED BY TRANSFIXING NEEDLE AND EXTERNAL PRESSURE.

The pressure is made by a piece of rubber tubing held against the nose by a rubber elastic band attached to a piece of adhesive plaster on the forehead and to the needle.

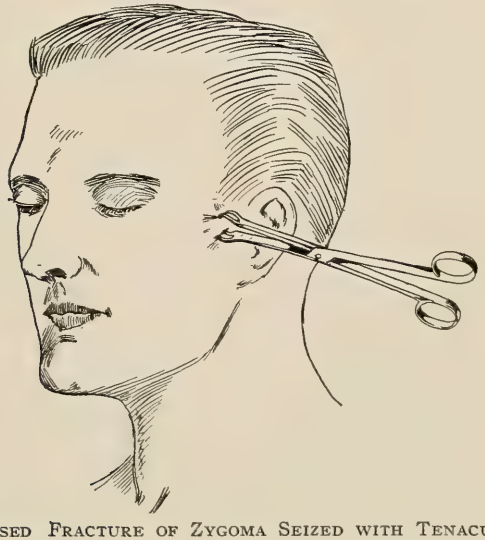


FIG. 396.—DEPRESSED FRACTURE OF ZYGOMA SEIZED WITH TENACULUM FORCEPS AND FRAGMENT DRAWN OUTWARD INTO POSITION.

bone has not been replaced. On the whole it is the best surgery to elevate the depressed bone at once. If open operation is required, it is done by making a very small incision through the skin, passing a strong hook under the bone and drawing the depressed arch outward into normal position.

Fractures of the Jaws

A most important part of the treatment of these injuries is the hygiene of the mouth. The teeth should be cleansed before splints or bandages are applied, and the mouth washed with mild antiseptic solution. After this the gums and teeth should be cleansed at least every two hours during the day with a swab of cotton on a holder. Peroxide of hydrogen and water, equal parts, is a good application. Decayed teeth should be temporarily filled. In cases in which the jaws are bound together, the patient should use a mouth wash, which can be rinsed in and out between the teeth every hour or two. This cleansing is important especially because these fractures are compound, and infection is very prone to occur; and because the general hygiene of the patient demands a clean mouth.

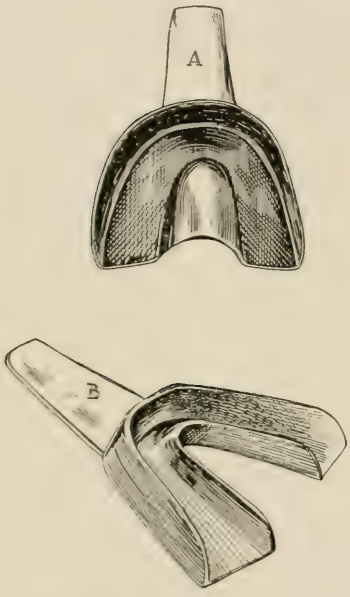


Fig. 397.—Modeling Cups for Making Impressions of the Teeth in Wax.

A, For upper jaw; *B*, for lower jaw.

Mastication should not be attempted during the healing of jaw fractures. The patient should subsist entirely on soft foods and liquids. These foods should be taken in the mouth and masticated with the tongue while they are being mixed with saliva and enjoyed. Soft eggs, milk, porridge, apple sauce and other soft foods should keep the patient in a good state of health.

The **interdental moulded splint** is one of the most important aids in the treatment of these fractures. A modeling composition is used by dentists for taking impressions of the teeth. The chief ingredient of this is wax. After the fracture has been reduced, and while the fragments are held in the desired position, some of this wax is placed in hot water to soften it. It is then placed in a cup, having the general contour of the jaw lines (Fig. 397), and while warm is pressed against the teeth, and the impression made. Upon being removed it cools and becomes hard, and a duplicate of the contour of the teeth and alveolar margins is made in this mould with plaster-of-Paris. Models are made both of the upper and lower jaws. This model reproduces the jaws and shows the positions of the teeth. Using this model a hard rubber or metal splint is made (Fig. 398). This is the sort of work that can best be done by a dentist. It is quite obvious the interdental splints are of no use in the treatment of fractures which do not involve the alveolar processes. Gold is to be preferred (Fig. 399).

Fractures of the upper jaw are of so great a variety that the mechanical ingenuity of the surgeon must be applied to each particular one, rather than any fixed rules of treatment. Usually these fractures are compound through involvement of the mucous membrane of the nose or mouth, or of the skin.

Surgery can always do much with these injuries, and good results can be secured even when the displacements seem to be horribly mutilating. The blood-supply to the superior maxilla is very rich, and it may be laid down as a rule that no fragment of bone should be removed so long as it has any periosteal connection. The power to heal possessed by this bone is wonderful. Loosened teeth will grow fast again if pressed back into their sockets. Displacements involving large parts of the bone may be reduced by the judicious use of the traction hook. Small retractors answer well for this purpose. A general anesthetic is often required. In order to secure a proper hold upon displaced fragments it may be necessary to incise the mucous membrane in the mouth.

If there is a tendency for fragments, bearing the alveolar process, to drop down they may be held up by placing a piece of cork or rubber between the teeth of the upper and lower jaw and binding the lower jaw against it (see Bandages of the Jaw). Sometimes the teeth of the lower jaw may be held tightly against those of the upper jaw, the patient being fed on fluids between

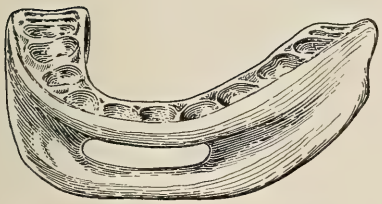


FIG. 398.—INTERDENTAL SPLINT OF VULCANIZED RUBBER.

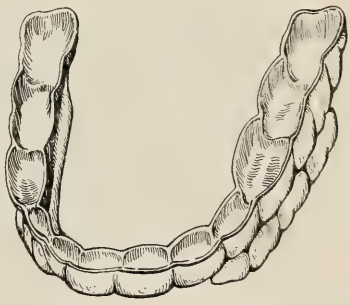


FIG. 399.—INTERDENTAL SPLINT OF GOLD.

missing teeth or by a tube passed through the nostril (see Nasal Feeding). Fractures of the alveolar process with a tendency to displacement are best held by means of an interdental splint, made of hard rubber or other firm material, after a model of the teeth made with dental wax. This is much more satisfactory than wiring. Occasionally a fracture is observed in which the fragments can be held by carrying silver wire around the teeth. The treatment of fractures of the alveolar process is more fully described under Fractures of the Lower Jaw.

Fractures of the lower jaw, with the exception of fractures in the extreme upper part of the bone, usually are compound fractures, communicating with the mouth by laceration of the mucous membrane. The nature of the fracture is determined by inspection and by passing a finger into the mouth. By manipulation the surgeon may easily determine how much force is required to correct the deformity and hold the bone in place, and in what direction the force must be applied.

In many cases the only treatment required is the application of a bandage, holding the lower jaw firmly against the upper jaw (see Bandages of the Jaw). In applying such a bandage it may be made more firm by incorporating strips of adhesive plaster to prevent slipping. In many cases there is a tendency to riding up of one side or the other. When this condition is present a wedge of rubber or other clean substance may be placed between the upper and lower jaw over the fragment which rides upward, and the jaws then

bandaged together (Fig. 400). The best material for making the wedge is a piece of rubber tubing split lengthwise. This is opened and sprung over the teeth. One or more thicknesses may be used.

I have used for many years with much satisfaction a simple device consisting of a cap of strong duck or drilling and a chin-piece of the same material or leather, connected by a rubber elastic band (Fig. 401). The strength of the pressure can be regulated, the thickness of the wedge changed at will, or pads placed under the jaw.

The application of a plaster-of-Paris bandage to the chin and head in some cases serves the best purpose. After this has been applied, a section

FIG. 400.—FRACTURE OF LOWER JAW.
Correction to be secured by pressure of bandage supplemented by rubber-tubing wedge between teeth and pad of gauze under depressed fragment.

may be cut out on either side, and the parts held by an elastic rubber band passed under the chin. The chin-cup of plaster-of-Paris is often more effective than one made of cloth or leather.

The *interdental splint* has proved most satisfactory in cases not amenable to the more simple methods of treatment. When the deformity can not be corrected for the taking of an impression, a clever dentist can reproduce the affected side by duplicating the sound side of the jaw or by dividing his cast at the fracture and making a corrected mould from the sound side of the jaw. In the absence of an impression a simple gutter splint, into which the teeth fit, is serviceable. An effective appliance is the Kingsley splint. This is an interdental splint having an impression of the lower jaw and bearing two

arms, which pass backward outside of the face, to which a bandage for supporting the jaw is attached (Figs. 402 and 403).

A modification of this principle adds a chin-piece which is connected to the lateral arms by rods, and so arranged that the chin-piece can be screwed up, pressing the jaw against the interdental splint (Fig. 404). R. Matas (Transactions Am. Surg. Assoc., 1904, vol. xxii) modified this principle, and made an adjustable, universal splint. The mouthpiece, or interdental splint, is made of soft metal (block tin), of which three sizes are made, and which can be adapted to any line of teeth. It is filled with wax or rubber composition for the teeth to rest in. This is connected by a hinged bar to a chin plate which when properly padded is screwed up against the under surface of the

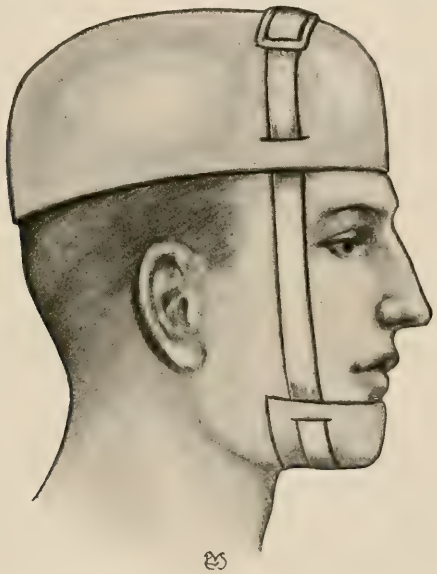


FIG. 401.—ELASTIC COMPRESSION BANDAGE OF JAW, USED BY AUTHOR.
A rubber elastic or elastic webbing makes continuous pressure upward.

jaw (Fig. 405). If necessary a bandage of the jaw and head may be added to this. These splints which involve only the lower jaw and do not depend upon pressing it up against the upper jaw give the best results and are the most comfortable for the patient. They have to be worn from two to four weeks, depending upon the tendency to displacement. Modifications of these may be required for special cases. Stimson reported once having used a carpenter's small wooden vise, one jaw of which rested upon the teeth, the other under the chin.

Wiring of the jaw is carried out by passing silver or copper wire about the teeth on either side of the fracture. This proves unsatisfactory in most cases unless a complicated system of wiring is used whereby both jaws are wired together. If wiring is done the best results are secured by drilling a hole through the depressed fragment and passing the wire obliquely around a tooth on the other fragment or through the bone (Fig. 406).

In exceptional cases a *plate* may be screwed to the outer surface of the bone (see Plate Treatment of Fractures, page 507), or a bone graft inlay may be used (page 517). The fact that most fractures of the jaw are compound often means infection of the fracture and necrosis of bone. It

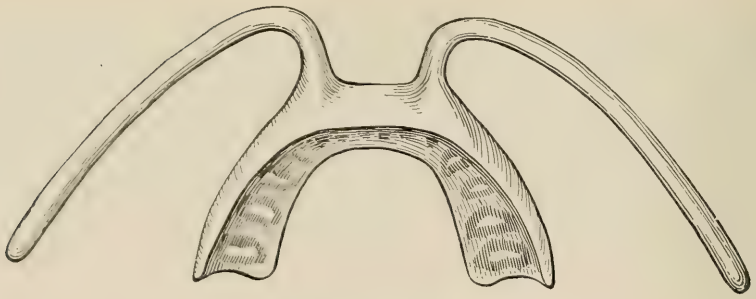


FIG. 402.—INTERDENTAL SPLINT OF KINGSLEY.

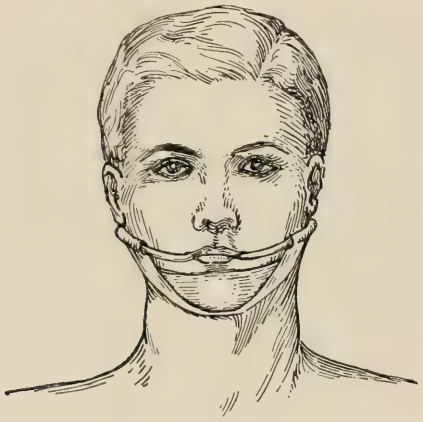


FIG. 403.—INTERDENTAL SPLINT OF KINGSLEY IN OPERATION.
The splint within the mouth makes downward pressure upon the teeth; and the bandage beneath the chin makes upward pressure.

FIG. 404.—INTERDENTAL SPLINT OF MORIARTY WITH CHIN-PIECE TO MAKE COMPRESSION.
In this splint the chin rests in a cup which can be screwed upward to increase the pressure.

sometimes may become necessary to open abscesses under the jaw and remove dead bone. These operations should not interfere with the persistence of treatment and the determination to secure a good result. Fistulas and sinuses sometimes develop; but even in the worst of cases good union should be expected. The cleansing of the mouth will contribute to the

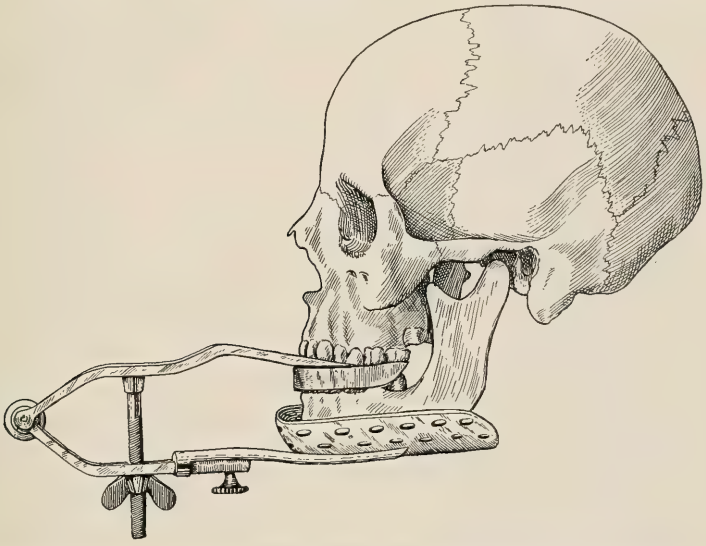


FIG. 405.—INTERDENTAL COMPRESSION SPLINT OF MATAS FOR TREATMENT OF FRACTURES OF LOWER JAW.

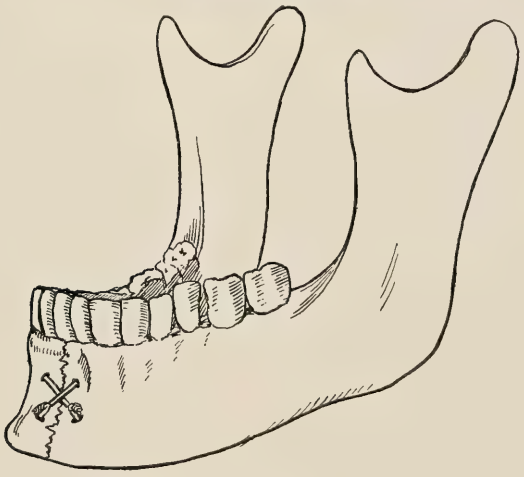


FIG. 406.—METHOD OF WIRING LOWER JAW TO PREVENT DISPLACEMENT.
Note that wire is passed in two oblique directions and twisted.

patient's comfort and restrain sepsis. Fluids and gruels pass into the mouth behind the molar teeth. When necessary they may be fed through a small catheter passed to the back of the mouth, outside of the teeth, between the teeth, or through the nose. Fractures of the *coronoid* and *articular processes* are treated by simple immobilization of the jaw.

Fracture of the Hyoid Bone

This injury usually occurs in one of the greater cornua near the body. The displacement is often distressing and urgently demands relief. Reduction is accomplished by inserting a finger in the mouth and placing the other hand over the bone on the outside of the neck. Swallowing causes painful motion of the fragments, and should be inhibited as much as possible. Nourishment should be given by rectum until enough exudate has been thrown out to hold the fragments together. When puncture of the mucous membrane has rendered the fracture compound, vigilance to meet the emergencies of cellulitis or edema of the glottis should be exercised. Profuse hemorrhage from the wound may demand pressure applied within the mouth or the introduction of a suture.

Fractures of the Sternum

Fractures of the sternum are usually observed near the line of union between the manubrium and the gladiolus, about the second intercostal space. The upper end of the lower fragment is commonly dislocated in front of the lower end of the upper fragment. Treatment must be directed, therefore, to depress the lower fragment or to elevate and bring forward the upper one. This can often be accomplished by strongly extending or flexing posteriorly the upper part of the dorsal spine by placing a sand bag or other body between the shoulders. The head also should be thrown back, by posterior flexion of the cervical spine, and flexed upon the neck in order to draw upon the sternomastoid muscles. An effort should then be made to draw down the ribs by placing the flat of the hands upon the chest assisted by adhesive plaster. At the same time the inner ends of the clavicles should be drawn upward, while the forward projecting fragment is pressed backward. The same result may be accomplished by placing the patient upon his back and allowing the head, neck and shoulders to hang over the end of the table. By grasping the arms and rotating them outward, as they are held above the head, the upper fragment is drawn forward into place.

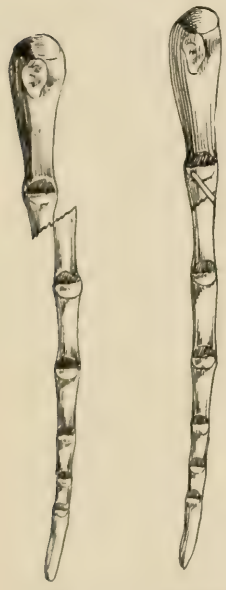


Fig. 407.—Fixing Displacement in Fracture of Sternum by Use of a Pin of Bone, Ivory or Metal.

Reduction is often accomplished but the fragments again slip out of place because of downward and backward obliquity of the fracture. Under such circumstances the well-equipped surgeon should fix the bones by the introduction of a bone peg, upward and backward, nailing together the two fragments (Fig. 407). Or for purposes of reduction the fracture may be exposed by a longitudinal incision and the bones pried into place by inserting a narrow instrument between them. Before attempting operation it should be recalled that infection of the anterior mediastinum is an extremely serious condition, and that many cases of fracture of the sternum heal with deformity and the patients go through life without apparent trouble.

In cases in which fracture of the sternum is complicated by mediastinal hemorrhage, usually from a branch of an internal mammary vein, the bleeding can often be reached by making a trephine opening through the sternum at the fracture.

Separation of the manubrium from the gladiolus may occur before the twenty-fifth year. Its treatment is the same as that of fracture.

Multiple fractures and fractures with unusual displacements require reduction by manipulation and extension. In some cases no displacement is present, or spontaneous reduction occurs. In all cases a broad band of adhesive plaster should be passed around the chest to secure as much fixation as possible. Union is fairly strong in four weeks, but from six to eight weeks are required for firm osseous healing. For safety in cases with a tendency to recur the patients should wear a spinal brace to keep the cervical and dorsal spines in constant posterior flexion.

Dislocations of the manubrium or ensiform process from the gladiolus are treated the same as fractures.

Fractures of Ribs

Usually in these fractures no displacement requires to be corrected, and fixation of the chest is all that is called for. When displacement is present it can be overcome as a rule by making pressure upon the projecting part. Often overriding or depression of a fragment can be cured by deep inspiration or by elevating the ribs by supporting the patient by his arms or axillæ. The depression of a detached fragment is best remedied by making a small incision over its middle and passing a hook to the inner side of it to draw it outward. If this does not suffice an open operation may be done and the bone sutured in place.

Fig. 408.—Fracture of Ribs Treated by Adhesive Plaster Strips.

For the immobilization of broken ribs the best means is by the application of an adhesive strip extending about three-fourths the way round the chest. The object of this band is to inhibit the motion of the ribs on the affected side. It should be put on at the end of expiration while the patient lies recumbent in bed with the arms by the sides. It should be wide enough to extend, in an adult, 8 or 10 cm. (3 or 4 inches) above and below the fracture. If but one rib is broken, it should be 10 or 15 cm. (4 or 6 inches) wide. The strip should be carried from the middle line behind, horizontally across, around to the front of the chest, and end at the anterior axillary line on the sound side. If ribs on either side are broken, it should pass all the way round the chest. If the chest has anything of a barrel shape, a better fit will be secured by using several narrower strips instead of one wide one (Fig. 408).

Each strip should overlap about one-third of the preceding one. The strips should be applied to the deflated chest at the end of expiration.

The emphysema of the subcutaneous cellular spaces sometimes present in these cases usually subsides in five or ten days. If it becomes troublesome a few punctures of the skin will allow the air to escape. Congestion of the lungs may occur as a complication of fracture. When this is observed in plethoric patients with high arterial tension, bleeding or other measures to reduce the tension are necessary to save life. Pneumothorax and hemothorax are considered under Injuries of the Thorax. Fractures of the costal cartilages require the same treatment as fractures of ribs. Sometimes a hard pad is necessary to keep a projecting end under control.

Fractures of the Clavicle

In most cases of fracture of the clavicle the break in the bone causes the shoulder to be retracted toward the thorax, thus producing overriding or angulation at the fracture. The indications for treatment, besides immobilization, are (1) extension on the clavicle by drawing the shoulder outward, (2) lifting up the outer end of the outer fragment, and (3) favoring these two conditions by throwing the shoulder backward. So strong is the tendency to overriding that, like oblique fractures of the humerus or femur, healing without some deformity is rare. In transverse fractures, which are less common, perfect healing may be secured. Whatever the position and however effective the immobilization, solid union takes place in most fractures of the clavicle. It is usually firm before the end of the fourth week. An immobilizing dressing is required for two to three weeks by children, and for three to five weeks by adults.

The treatment is practically the same for fracture in any part of the clavicle. The shoulder with the outer fragment is usually displaced inward, downward and forward. The outer end of the inner fragment is drawn upward. To overcome these deformities many different methods of treatment have been devised. In transverse fractures, a little pressure upon the bone may suffice to keep it in place, and with the arm simply carried in a sling hung about the neck a good result may be secured.

The **recumbent treatment** in many cases is decidedly advantageous. If the patient is laid recumbent upon a hard mattress with a small pad between the shoulders and a pillow to raise the head, perfect reduction is observed, and healing may be secured without any dressing whatever. This method is improved by slightly raising the arm on the injured side upon an incline so as to cause the shoulder to be pressed upward, or by binding the arm to the side to insure less mobility. In the simultaneous fracture of both clavicles, this treatment is to be preferred.

The **rest treatment** of fractures was popularized and perfected by Couteaud (Trans. Acad. Med. Paris, May 5, 1914). As soon as possible the patient is placed in what is called the first position. He lies on his back on a firm mattress, with the arm of the injured side hanging over the side of the bed (Fig. 409). A pillow is allowed under the head. This position is maintained for an hour or an hour and a half. During this time displacement becomes spontaneously corrected. Then the second position is assumed. This consists in allowing the arm to hang as before, but with the elbow bent at a right angle; the forearm rests on a pillow on a chair at a level slightly lower than the elbow. The support should be so low that there is still some gravity pull upon the shoulder. If more convenient or comfortable the wrist may rest in a sling made fast to the side of the bed.

This position must be maintained day and night for about seven days. A sling may be passed about the chest and made fast to the other side of the bed to prevent the patient falling out. After that the patient takes the third position, which consists in lying supine with a pillow between the shoulders and with the arm at the side. By the end of ten days the patient may be allowed to flex the forearm on the elbow.

This method is especially of value in cases which come for treatment during the first twenty-four hours. Callus forms about the fourth day; it is hard by the end of the first week; and by the eighth or tenth day, it is resistant enough to allow the patient to get up and carefully move about.

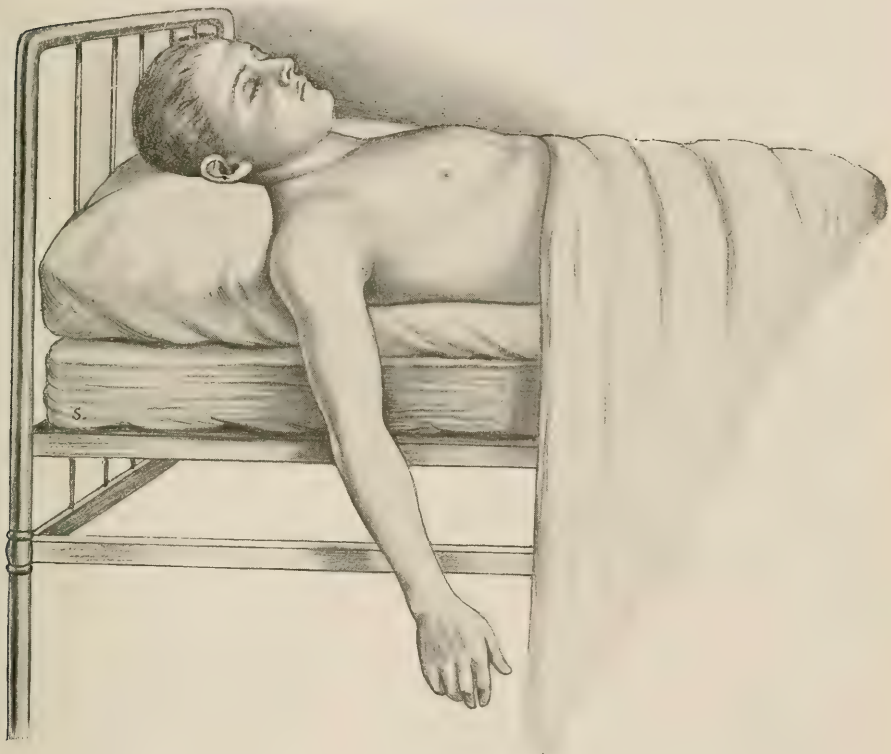


FIG. 409.—REST AND GRAVITY TREATMENT OF FRACTURE OF RIGHT CLAVICLE. First position: The arm hangs naturally at the side of the bed until displacement becomes corrected.

Treatment with Bandages and Adhesive Plaster is Most Used.—A simple device which I have found satisfactory in cases with moderate displacement, is as follows:—A pad of gauze is placed in the axilla; a 10-cm. (4-inch) strip of adhesive plaster is carried around the upper arm, across the back and around the chest to the arm again. This holds the axillary pad, draws the arm and shoulder backward, presses the arm to the side and throws the shoulder outward. Over this is pinned a muslin binder or bandage about 15 cm. (6 inches) wide. A flat gauze pad is laid on the clavicle. The elbow is flexed at a right angle, the forearm lying across the front of the body. A strip of adhesive plaster 9 cm. (3½ inches) wide is carried from a point

behind the sound axilla obliquely upward and across the back, over the broken bone vertically down in front of the chest-binder, under the flexed forearm near the elbow, upward behind the axilla, over the broken bone again to the axilla of the sound side, lying partly on the skin, partly on the pad over the clavicle, and partly on the chest-binder. A loop of adhesive plaster is carried around the wrist, thence over the fracture and pinned to the binder behind, to serve as a sling and make additional pressure on the clavicle

FIG. 410.—REST AND GRAVITY TREATMENT OF FRACTURE OF CLAVICLE.
Second position: The forearm rests on pillow which should be low enough to impose some traction upon the shoulder.

(Fig. 411). Where there are hairy parts, the adhesive plaster should be preceded by a muslin bandage. A muslin or gauze bandage may be applied over the adhesive strips. This embraces most of the principles of the dressing of Sayre.

A modification of the dressing introduced by Sayre of New York is most commonly employed. A pad of a few layers of gauze or a small towel is placed along the side and front of the chest from the axilla to the level of the elbow, the parts being well powdered. This is held in place by a small adhesive strip and is intended to keep apart the skin of the arm and chest. The upper part of the arm is then encircled with two or three layers of flannel bandage about 9 cm. (3½ inches) wide. The end of a strip of

adhesive plaster 9 or 10 cm. (3½ or 4 inches) wide is then applied over the flannel bandage and pinned behind the axilla so that a loop is made. The forearm is flexed across the chest and the upper arm and shoulder are strongly drawn backward and inward by the adhesive plaster, which is applied across the back and around to the front of the chest on the sound side as far as the sternum.

The hand is well powdered and laid upon a pad of gauze on the front of the upper part of the chest on the opposite side. A second strip of adhesive plaster of the same width is started over the scapula of the sound side, passes obliquely down to the elbow of the injured side, a small

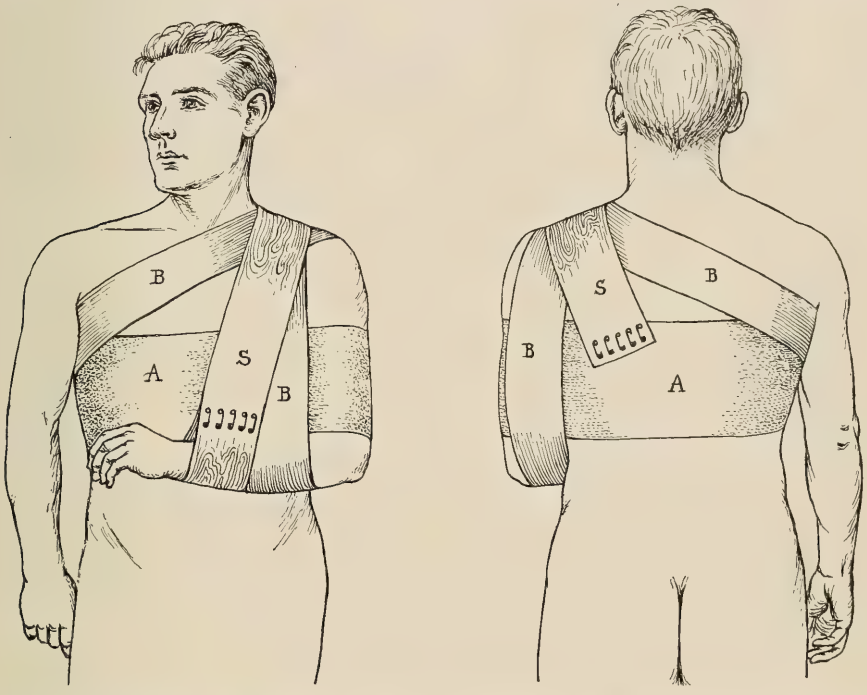


FIG. 411.—METHOD EMPLOYED BY AUTHOR FOR DRESSING FRACTURES OF CLAVICLE. *A*, Muslin binder, applied first; *B*, adhesive plaster, next applied; *S*, sling of adhesive plaster, last.

hole being cut to receive the point of the elbow, forward around the elbow, upward along the forearm and dorsum of the hand and terminates behind the sound shoulder at the place of beginning. This last strip is applied in such a way as to lift up the shoulder by supporting the elbow (Fig. 413). A third adhesive strip is now carried horizontally around the body and across the elbow in order to hold the latter close to the trunk (Fig. 414).

Usually it will be found when this dressing has been applied that the deformity is about corrected. In some cases with much overriding a larger pad of gauze in the axilla, over which the humerus may operate as a lever to throw the shoulder outward, may be of service. Sometimes a little additional pressure must be made on the inner fragment; but never directly on the fracture unless a pad of gauze is interposed. Often the horizontal adhesive strip may be omitted. Over all, a chest-binder may be applied or

a shoulder bandage (see Bandages). In some cases it will be found desirable to make firm pressure on the clavicle. This may be done with adhesive straps carried over the shoulder from the level of the nipple to the lower angle of the scapula. Adhesive strips may require to be renewed every two or three weeks.

Other dressings are used to meet special conditions. In some cases the chief indication is to hold the shoulders back. This can be done by a figure-of-eight bandage across the back (see Bandages). In order to prevent pressure

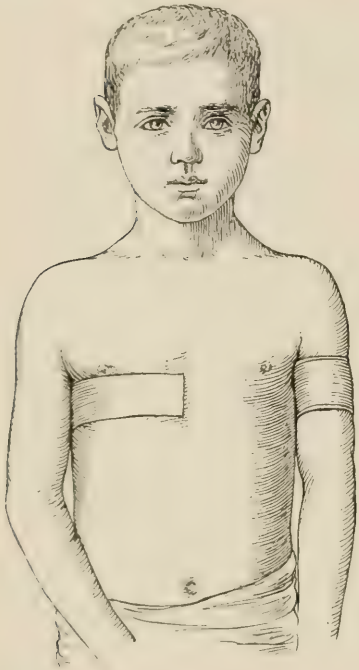


FIG. 412.—FRACTURE OF CLAVICLE.
First strip of adhesive plaster applied to draw shoulder backward.

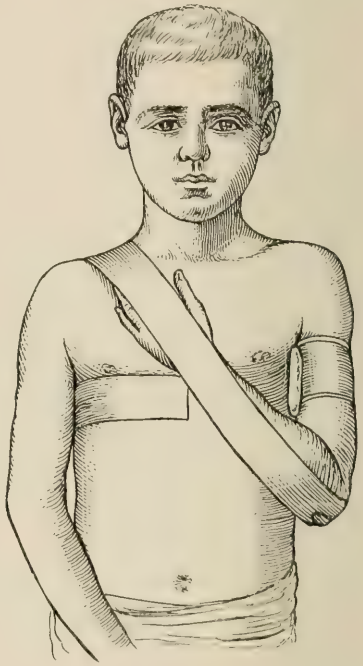


FIG. 413.—FRACTURE OF CLAVICLE.
Second strip of adhesive plaster applied to lift up shoulder and tilt down the fracture. Note pad of gauze in axilla.

upon the axillary vessels a flat cuirasse of leather or plaster-of-Paris bandage should be placed in front of each shoulder. Modifications of these dressings must often be made to meet special indications. One of these which I have used with much satisfaction consists in a bandage which makes pressure upon the clavicle at the same time that it holds the arm and forearm. The forearm of the affected side is flexed at a right angle across the front of the chest. A 10-cm. (4-inch) muslin bandage is started in the middle of the back, carried over the diseased clavicle, under the forearm, back over the shoulder again, diagonally across the back, under the axilla on the sound side, horizontally across the front of the chest, across the upper arm, and to the point of starting, where the three layers are made fast together. The bandage should be strong and heavy. The first adhesive strip of the Sayre dressing may be combined with this. It is of service as a warm weather dressing in cases with not a great tendency to displacement.

A simple plaster-of-Paris shoulder spica (see Bandages) answers admirably in some cases. The fragments being held in position while the plaster hardens. The forearm is carried in a sling which is made fast to the front turns of the spica anterior to the xyphoid appendix.

A satisfactory dressing is that of J. A. Nydegger (Jour. Am. Med. Assoc., July 3, 1909). The elbow is drawn back and pressed upward so as to elevate the shoulder. A strip of adhesive plaster 9 cm. (3½ inches) wide and about 125 cm. (4 feet) long is passed from within outward about the middle of the arm, thence horizontally across the back and around the chest just as the first strip is applied in the dressing of Sayre. A muslin bandage 10 cm. (4 inches) wide then is begun at the side of the neck above the injured bone and passes outward toward the shoulder, downward in front of the chest, thence beneath the forearm, upward behind the arm, over the shoulder, diagonally across the front of the chest to the opposite axilla and across the back to the place of beginning. This bandage is continued for several layers in this same path. This bandage takes the course of a figure-of-eight, the head and sound shoulder occupying one loop and the arm of the injured side the other loop. A third bandage is carried around the arm and chest lying on the adhesive strip; and a sling is fixed under the wrist by carrying some of the turns of the second bandage forward on the forearm.

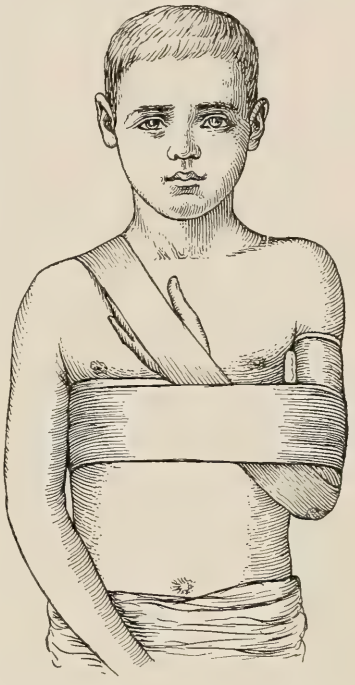


FIG. 414.—FRACTURE OF CLAVICLE. Third adhesive strip presses elbow inward and throws shoulder outward.

In green-stick fractures or transverse fractures with some of the periosteum untorn the only dressing required may be a simple sling to which is added a bandage to hold the arm and forearm against the chest. Fortunately when there is displacement, deformity in the healing of the bone does not often cause defective function. It is possible for the subclavian vein or artery to be injured by the fragments. The brachial plexus has been involved in callus and inflammatory exudate which has required operation for its relief.

In children and persons with tender skin the dressings should be removed frequently and the skins bathed and powdered. Gauze should always be interposed where skin surfaces lie together. As soon as union is firm enough plaster or tight bandages should be removed and a simple sling and chest bandage substituted. A laboring man may expect to be back to work inside of two months.

Operative treatment is called for in multiple or comminuted fractures with irreducible displacement, also in fractures in which there is much deformity or in which sharp points of bone threaten the vessels, nerves or skin. It may also be applied in cases of non-union. The fracture is exposed by an incision just behind or in front of the clavicle, the fragments are united by chromic gut sutures passed through the bone or periosteum and

the shoulder immobilized by one of the above-described dressings. Or a bone-grafting operation may be done.

Fractures of the Scapula

Fractures of the **acromion process** require first that reduction be made by pushing up the head of the humerus and pressing down the inner fragment. The dressing which is generally most effective is a firm bandage which holds the forearm acutely flexed across the chest, makes pressure upward upon the elbow and downward upon the inner fragment (see Bandages, Vol. III). A dressing which I have applied with satisfaction in these cases has consisted of a pad over the inner fragment, held down by an adhesive strip 5 to 8 cm. (2 or 3 inches) wide, and ending behind and in front just below the shoulder; this is connected by strong rubber elastics, behind and in front, with a similar strip passed under the elbow; the humerus is held to the side by a bandage about the thorax; and the forearm is supported in a sling. Union is firm in from four to six weeks.

Fracture of the **coracoid process** is best treated by binding the humerus to the thorax by a circular bandage and supporting the forearm in a sling. To this may be added an adhesive plaster strip across the shoulder or a simple shoulder bandage.

Fracture of the **neck** of the scapula is usually complicated by a tendency to downward displacement. This is best overcome by supporting the forearm in a sling and lifting up the humerus by passing an adhesive strip 5 or 8 cm. (2 or 3 inches) wide over the shoulder and under the elbow, the elbow and shoulder being lightly padded. This strip must be tightly applied. The humerus is held tightly to the side by a bandage around the chest. A good thick pad of gauze should be interposed between the upper arm and chest to counteract inward displacement of the head.

Treatment of fractures of the **head of the scapula** should be aimed to prevent the humerus from escaping from its socket. A thick pad of gauze should be placed between the upper arm and the thorax, and the arm immobilized to the chest in such a way as to make outward traction on the head of the humerus.

Fractures of the **body of the scapula,** after reduction by manipulation has been accomplished, are best controlled by supporting the forearm in a sling, and holding the upper arm to the chest by an encircling bandage with a pad between. Previous to applying this dressing, an adhesive plaster strip 8 or 10 cm. (3 or 4 inches) wide may be passed over the clavicle and down over the scapula, and another similar strip transversely across the back of the chest across the scapula.

Fractures of the **upper angle of the scapula** and of the **spine** are treated by the last-described method.

Fractures of the Humerus

The treatment of fractures of the humerus varies with the location of the fracture. Fractures above the insertion of the shoulder muscles are so closely associated with the shoulder-joint that their peculiarities should be well understood before treatment can be satisfactorily carried out. Fracture of the shaft is similar to fracture of the shaft of the femur. The fractures of the lower extremity require especial consideration for the elbow-joint.

Fractures of the Upper Extremity of the Humerus.—*Fractures of the head* cannot often be differentiated from fractures involving the anatomical neck. The diagnosis by the *x*-ray is a valuable aid in treatment, as the real nature

of the fracture and the degree of deformity can not be discovered by other means. Usually an immobilizing bandage suffices, but in many cases some extension will be of advantage to overcome the strong upward traction made on the lower fragment by the muscles. The extension is applied by means of two adhesive strips, connected below the elbow, and carrying a weight of 5 or 10 pounds when the patient is up, and hooked to a pulley and weight at the foot of the bed when the patient lies down. This extension dressing should be used in connection with the shoulder spica and immobilization of the arm by binding it to the body (see Traction, page 487).

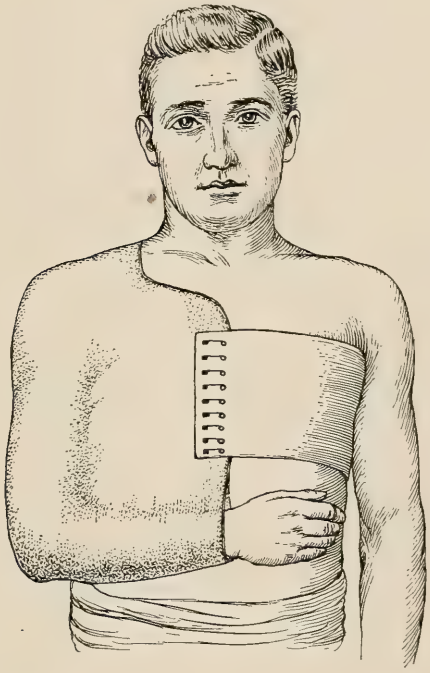


FIG. 415.—SPICA OF PLASTER-OF-PARIS IN TREATMENT OF FRACTURES OF UPPER END OF HUMERUS.

The spica of the shoulder has been covered by a continuation of the bandage embracing the trunk and arm and forearm. Then the bandage has been cut in the middle line in front and behind, and the half which embraced the chest of the sound side substituted by a cotton binder, which is pinned to the plaster-of-Paris dressing while the latter is still soft.

Fractures of the anatomical neck are treated the same as fractures of the head. These fractures sometimes are combined with fractures of the head. They may also run into the tuberosities. The use of extension depends upon whether the fracture is complete and separates the upper fragment. Any tendency to inward displacement of the lower fragment should be treated by a firm pad in the axilla, combined with adduction of the elbow.

Fractures of the tuberosities are not common. The natural treatment of fracture of the greater tuberosity is fixation of the humerus in a position of outward rotation; and inward rotation in fracture of the lesser tuberosity. If extreme separation is present, fixation by suture or nailing is called for.

Fractures of the surgical neck include the fractures between the epiphyseal line and the insertion of the pectoralis major and the teres major. They are the common fractures of the upper end of the humerus. The fractures near the tuberosities are apt to be transverse; those lower down are usually oblique. The deformity which most frequently requires to be considered is abduction of the upper fragment and inward displacement of the lower fragment. If the fracture is oblique, overriding is present; but even in transverse fractures it is often observed.

In fractures with but slight displacement, in the form of overriding and adduction of the lower fragment, if slight longitudinal traction is made the

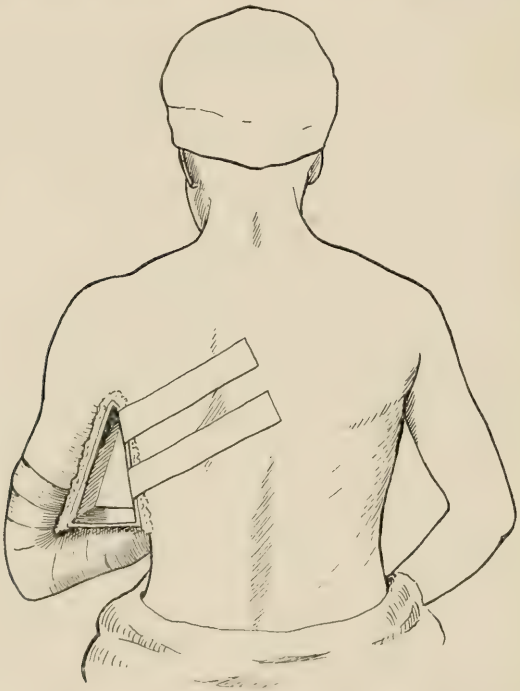


FIG. 416.—TRIANGULAR SPLINT USED IN TREATING FRACTURES OF THE UPPER END OF THE HUMERUS.

two fragments can often be caused to engage and displacement is overcome. A little traction, secured simply by the weight of the arm, and a splint often suffice to give a good result. The most satisfactory splint is the shoulder spica (see Bandages, Vol. III), applied with an 8-cm. (3-inch) plaster-of-Paris bandage, to which is added a simple plaster casing of the arm and forearm, the elbow being flexed at a right angle. Before applying the plaster, the axilla should have been cleansed with soap and water, rubbed with alcohol, dried, well powdered and covered with a few layers of gauze. The arm and shoulder should be covered with a part of a cotton undershirt or with a flannel bandage. The elbow should be held slightly away from the body and the forearm supported at the wrist by a sling. After applying the spica which embraces the upper arm and shoulder, it may be covered with a bandage around the body, embracing the arm and forearm.

The shoulder spica may then be cut in front and behind at the middle line, and for the plaster encircling the chest a stout piece of bandage may be

substituted, being pinned to the cut edges of the plaster spica (Fig. 415). By making some traction upon the lower fragment as the forearm is held at a right angle and as the plaster is applied about the elbow, a purchase of resistance is secured below, and continuous extension is maintained.

If still more extension is required adhesive plaster strips should be placed on the arm and connected below the elbow so that a weight can be attached when the patient is up and traction connected by a rope and pulley when the patient is in bed. Five or 10 pounds are usually enough. If traction is thus applied, the plaster case should only extend down as far as the elbow; the forearm should be covered with a flannel bandage to prevent swelling,

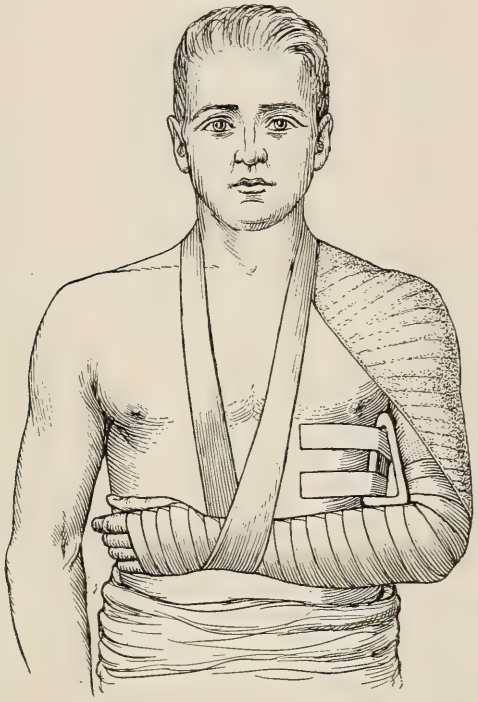


FIG. 417.—SHOULDER CAP, SLING AND TRIANGULAR SPLINT IN TREATMENT OF FRACTURE OF UPPER END OF HUMERUS.

and carried in a sling horizontally in front of the body. The sling should support only the wrist.

In cases in which the abduction of the upper fragment is pronounced it will often become necessary to put up the lower fragment in abduction in order to keep its axis in line with that of the former. This can be done by traction in that position in bed for two weeks, at the end of which time it will be found that the two fragments have become firmly enough united to allow putting up the arm in a simple plaster-of-Paris dressing. If it is not desired to keep the patient in bed abduction may be maintained by placing a triangular pad or splint between the humerus and the side of the chest, and bandaging the arm to the body. Extension may be added to this.

If the chief deformity is inward displacement of the upper end of the lower fragment, this may be overcome by a pad between the upper arm and the chest. Rarely it will be necessary to make outward traction, at a right angle to the bone, by means of a weight and pulley.

A very satisfactory dressing, and applicable to a large proportion of cases, is the following:—A triangular pad or frame is supported at the side of the chest. The forearm is enveloped in a flannel bandage and supported by a sling (Fig. 416). To this may be added a shoulder cap made of a few layers of wide plaster-of-Paris bandage, and simply fitting the top, back, front and outer side of the shoulder and the outer part of the upper arm (Fig. 417). This cuirasse may be held on after it is hard by a broad bandage passing around the chest (Fig. 418).

In fractures with much displacement, manipulation and extension may fail to give satisfactory reduction; in which event the well-equipped surgeon

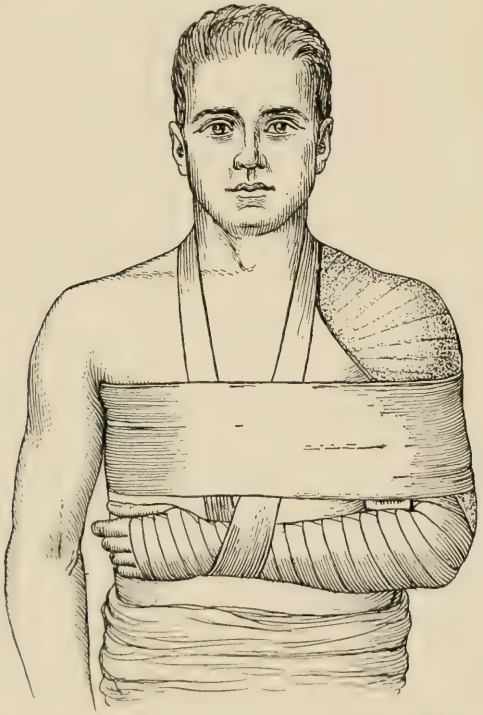


FIG. 418.—FRACTURE OF UPPER END OF HUMERUS.
Shoulder cap, triangular splint in axilla, sling for forearm, breast binder, complete.

should expose the fracture by open operation and fix the bones together (see Operative Treatment of Fractures).

The dressings should be removed in these fractures for inspection every week or two. If good apposition is secured soft union is present in two weeks. By the end of four weeks passive motion may be made and the arm simply bandaged to the side.

Fractures of the shaft of the humerus are commonly associated with overriding and inward displacement of the upper fragment. Reduction is accomplished by traction upon the flexed elbow. Lateral coaptation splints, combined with traction, usually suffice to secure good position. Good immobilization is important because of the danger of non-union, which is very common in this fracture; and good reduction is important because of this and also because of the danger of damage to the musculospiral nerve. Immobilization with abduction is necessary in the cases with

the characteristic deformity. A splint devised by D. P. Penhallow (Jour. Am. Med. Assoc., July 31, 1909) meets the requirements in most cases (Fig.

FIG. 419.—FRACTURE OF SHAFT OF HUMERUS ON ABDUCTING SPLINT OF PENHALLOW
Bandage is omitted.

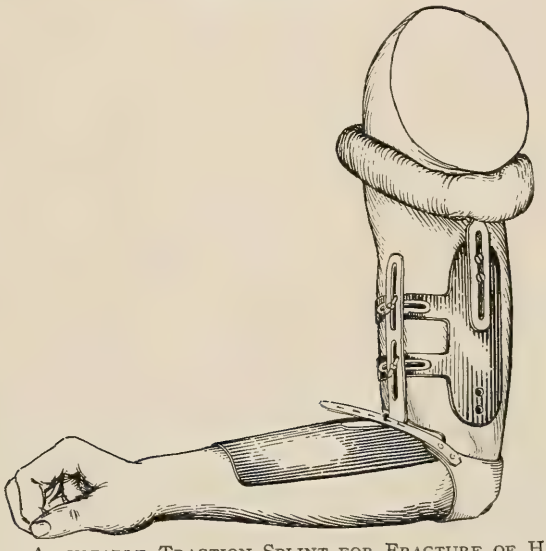


FIG. 420.—ADJUSTABLE TRACTION SPLINT FOR FRACTURE OF HUMERUS.
This splint, with its axillary pressure-pad and the adjustable sliding piece for the upper arm, is capable of making constant traction on the fracture.

419). It is a triangle, the chest, the upper arm, and the forearm lying against the three sides. It is attached by adhesive straps and bandages, and gives abduction and traction.

Many forms of splint have been devised for making positive traction. The adjustable apparatus with a sliding frame (Fig. 420) is of this sort and has much to recommend it. The axillary piece which embraces the upper arm should be well padded before applying the splint. The arm should be protected by adequate bandages.

In fractures with slight displacement a satisfactory dressing is applied as follows:—The axilla is washed, dried, and well powdered. A pad made of eight or ten layers of gauze is laid along the inner side of the arm. The forearm, arm and shoulder are covered by a smooth flannel bandage. A plaster-of-Paris splint, 30 or 35 cm. (12 or 14 inches) long and 8 or 10 cm. (3 or 4 inches) wide, is made by laying together on a table several thicknesses

FIG. 421. — FLEXIBLE SPLINT, MADE BY LAYING NARROW STRIPS OF WOOD ON ADHESIVE PLASTER.

FIG. 422.—FRACTURE OF MIDDLE OF HUMERUS TREATED BY TRIANGLE IN AXILLA, AND FLEXIBLE SPLINT, TO BE COVERED BY BREAST BINDER.

of moistened plaster bandage and rubbing them together. A stiff wooden splint, preferably the flexible splint (Fig. 421), is placed about the inner side of the arm from the axilla to the inner condyle. The plaster splint is placed on the outer side of the arm and top of the shoulder, extending from the root of the neck to the outer condyle. Upon the plaster, from the condyle to the shoulder, may be placed a flexible basswood splint. The splints are held in place by three circular adhesive straps. A 5-cm. (2-inch) muslin bandage is then applied from the elbow to the axilla, and then a spica of the shoulder. The forearm should be held across the front of the body by a sling about the neck and supporting the arm at the wrist. No splints should press upon the condyles. Motion at the elbow-joint should not be restricted, except by the bandages and sling. This dressing is more comfortable than that in which the arm is bandaged to the chest.

If there is no displacement the simple flexible splint alone may be used (Figs. 422 and 423).

Another very useful dressing is similar to the above in every respect except that the plaster-of-Paris splint is made to envelop the elbow just as it does the shoulder. By making downward traction upon the elbow while the dressing is being applied, this dressing may be used in cases in which considerable deformity must be corrected.

In fractures with much displacement traction is necessary. This is best applied by laying a 5-cm. (2-inch) strip of adhesive plaster along the inner and outer sides of the arm, extending up to the fracture. At the elbow should be

FIG. 423.—FRACTURE OF MIDDLE OF HUMERUS, TREATED WITH TRIANGLE IN AXILLA, FLEXIBLE SPLINT, BROAD BINDER, AND SLING.

placed a block of wood as wide as the plaster and about 7 cm. (2½ inches) long. This should be put in the adhesive plaster sling as it passes under the elbow, and should be about 2 or 3 cm. (1 inch) below the skin. This spreader should have screwed into its middle a small screw eye, to which a 5- or 10-pound weight can be hooked when the patient is about, and to which a cord connected by a weight over a pulley at the foot of the bed may be attached at night. Over the adhesive plaster the same splints may be applied as are described above for the treatment of fractures with slight displacement (see also Treatment by Traction, page 487).

In fractures in which slight traction will correct the deformity, a good splint can be made of plaster-of-Paris. The arm and chest are covered by a cotton undershirt. The forearm is flexed at a right angle, and a 10-cm. (4-inch) plaster-of-Paris bandage is applied to the upper arm. An 8-cm. (3-inch) plaster bandage is applied to the forearm and elbow, and a spica of the same material to the shoulder. While these bandages are being applied a good assistant makes traction, holds the forearm flexed and maintains the fragments in position. A few layers of plaster bandage are

carried from the wrist (the lowest part of the plaster case) upward to be incorporated in the spica behind and in front of the shoulder and chest. This last bandage supports the forearm and prevents outward displacement of the splint. This dressing need not be thick. If the layers of plaster are well rubbed in as they are applied a strong splint is made with little bandage. At the end of a week or two, or sooner if the patient desires it, the part of the spica passing around the chest may be cut away from the middle line in front and behind, and a stout piece of cloth may be pinned to the cut edges to take its place. At the end of two or three weeks the plaster case may be bisected by cutting it, from the root of the neck, over the back of the shoulder, down the back of the arm, and under side of the forearm; and from the front of the neck to the axilla, along the front of the arm, and upper side of the forearm. The arm may be inspected and the splint replaced.

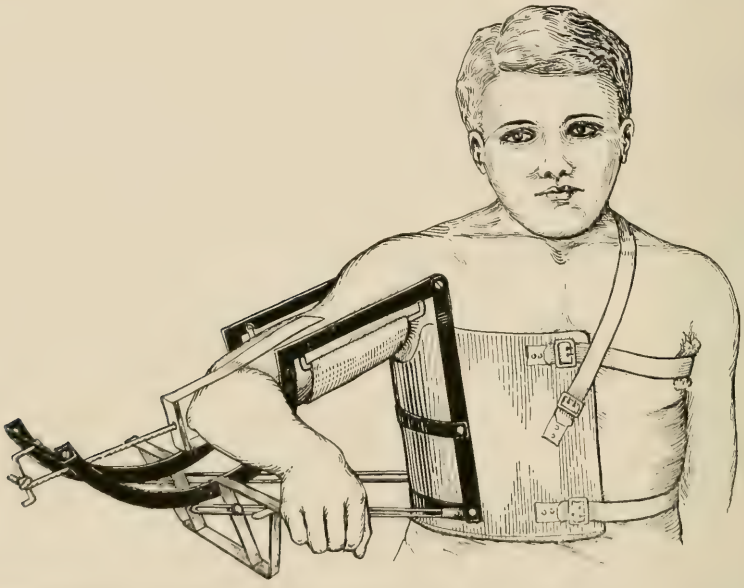


FIG. 424.—SCAFFOLD SPLINT TO GIVE ABDUCTION AND TRACTION IN FRACTURE OF HUMERUS.

Traction may be applied through a cord or by adding a rubber elastic band.

Other cases may be treated in bed for the first two weeks with extension or with the arm fixed to a triangular pad at the side of the chest.

The *scaffold splint*, much used in France, which gives abduction and traction, is most effective in cases requiring these two forces. The splint is light; it gives abduction to a right angle; and continuous traction may be applied (Fig. 424).

Non-union or delayed union are not so much due to mobility as they are to imperfect reduction. Union in fractures of the humerus should be fairly solid in four weeks, and the arm may be used after eight weeks. If consolidation is not present by the sixth week, and the position is good stimulation of the local blood-supply is called for (see Delayed Union, Fractures, page 527). If after two or three months union is still soft, operative treatment is indicated.

Disturbance of the musculospiral nerve may be due to contusion, laceration or involvement in callus or exudate; and after the best possible

reduction of the fracture has been secured, results should be awaited. If paralysis persists, the nerve should be exposed. It may require to be sutured or liberated from compressing exudate.

Compound fractures of the shaft usually need no further splinting than a copious dressing for the wound and a sling for the forearm. If the nerve has been divided it should be sutured as soon as an aseptic condition of the wound obtains.

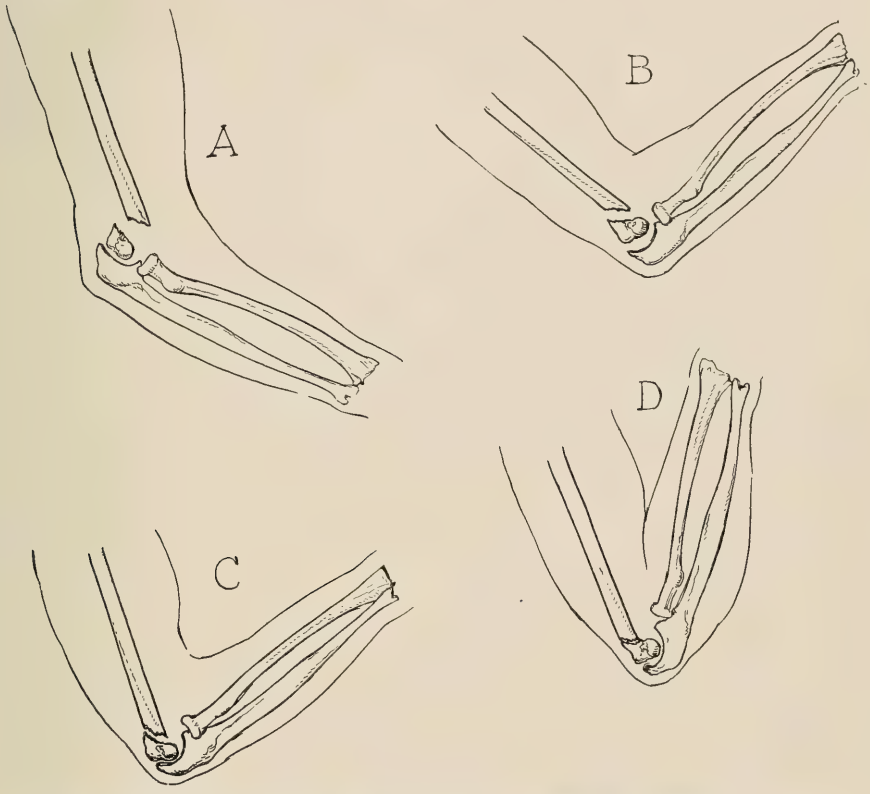


FIG. 425.—FRACTURE OF LOWER END OF HUMERUS, SHOWING EFFECT OF FLEXION. *A*, Obtuse flexion, position bad; *B*, right angle flexion, position improved; *C*, acute flexion, position better; *D*, extreme flexion, position perfect.

Usually in fractures of the shaft, splints may be dispensed with at the end of four weeks; but, to prevent bending, coaptation splints and a sling may be used until the end of six weeks, passive motion being applied to the shoulder and elbow from the third or fourth week.

Fractures of the lower extremity of the humerus are often called fractures of the elbow. Diagnosis is very essential for satisfactory treatment. The *x*-ray is invaluable. There are many lesions which cannot be determined by external examination, nor can the surgeon know whether he has secured correction or not. Some surgeons treat all fractures of the elbow in extreme flexion; others treat them with the elbow flexed at a right angle; and others with the elbow at a slightly obtuse angle. But really no two cases are alike. The fact that some fractures of the lower end of the humerus may be corrected by flexion and others by extension and still others by either method

of treatment must be learned by all surgeons. The value of flexion is illustrated in the accompanying *x*-ray pictures (Fig. 425) of cases from my practice. (J. P. Warbasse: Some Common Injuries of the Elbow, Med. Record, Jan. 30, 1909.)

To determine the degree of bony displacement, or the perfection of replacement, the injured side should be compared with the other arm. With a pencil or ink the three bony points of the elbow should be marked: the tips of the internal and external condyles and the tip of the olecranon. With the arm straight these three points should be nearly in a straight line; with the elbow at a right angle they should make approximately an equilateral

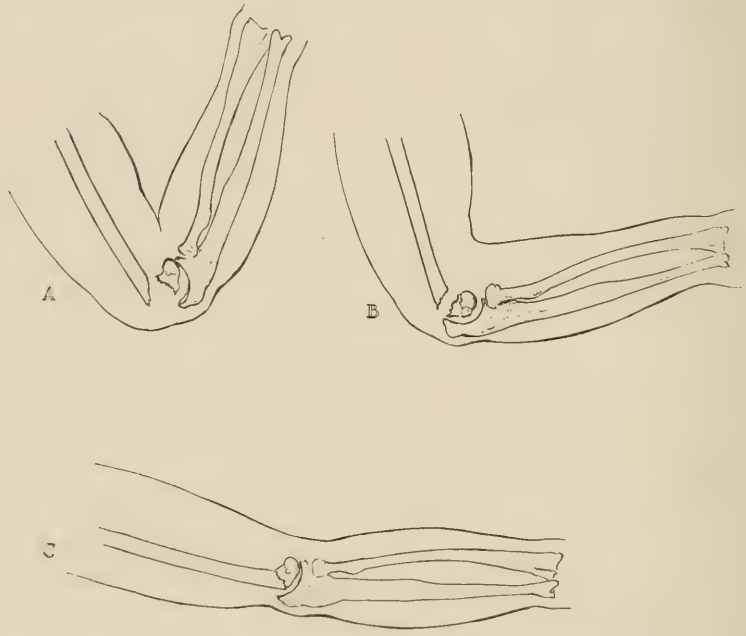


FIG. 426.—SUPRACONDYLOID FRACTURE, SHOWING EFFECT OF FLEXION AND EXTENSION OF ELBOW.

A, Elbow flexed at an acute angle, position bad; *B*, elbow flexed at right angle, position better; *C*, elbow fully extended, position perfect.

triangle. Even when there is much swelling, steady pressure will reveal these points. The head of the radius should be felt, and with both arms extended the carrying angle of the two sides may be compared.

In these fractures there is a tendency to upward displacement. Commonly there is also backward displacement of the lower fragment. It is this backward displacement that is corrected by extreme flexion. Forward displacement is often best treated by the right angle position of the elbow or by extension to the straight position (Fig. 426).

There should be no hesitancy to use a general anesthetic in the diagnosis and treatment of these fractures. The old idea of waiting for the swelling to subside before doing anything is not good. Treatment should be applied as soon as possible after the injury. The best way to get the swelling to subside is not by applying evaporating lotions but by replacing the fragments and immobilizing the part. Operative treatment is often indicated.

After exposing the fracture and replacing the fragments, they may be held by suturing the overlying soft parts, or by pegs (Fig. 427).

Supracondyloid fractures require slight downward traction while the arm and forearm are put up at a right angle. The arm should be covered with a flannel bandage or other covering and immobilized with a right-angle splint, extending from the axilla to the wrist. For this purpose an anterior splint of metal may be used. The tendency to upward and backward displacement of the lower fragment should be overcome by traction and forward pressure,

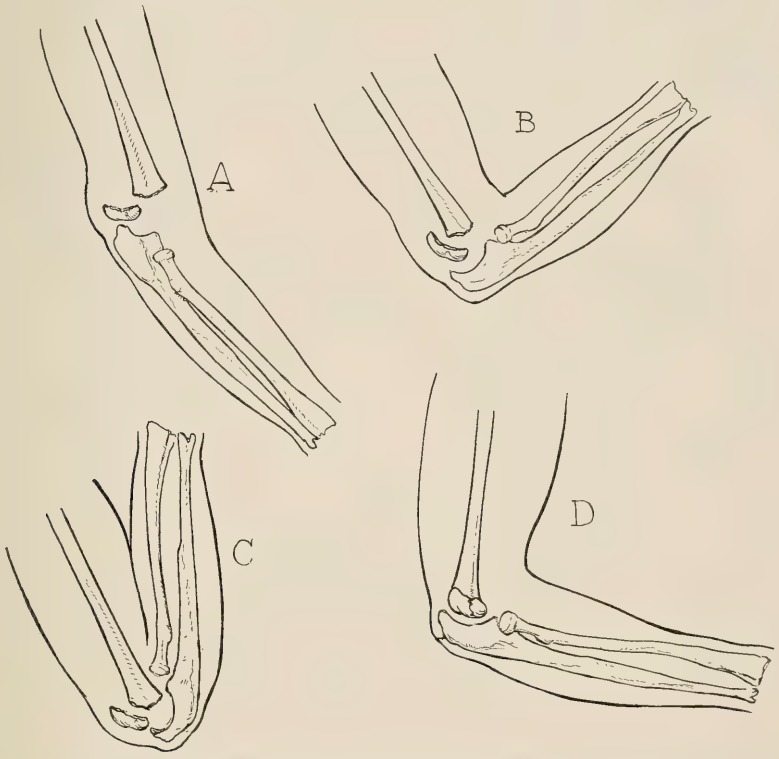


FIG. 427.—SEPARATION OF LOWER EPIPHYSIS OF HUMERUS.

A, Elbow straight, position bad; *B*, elbow flexed, position bad; C, elbow acutely flexed, position bad; *D*, result after open operation, position perfect. From case operated on by author.

the splint applied and bandaged in place. The splint should not be sharp but rounded at the angle so that pressure upon the coronoid process is not made. It should be smoothly padded with gauze, pressed backward firmly against the front of the humerus and held in this position by an adhesive strip, 2.5 to 5 cm. (1 to 2 inches) wide, attached on either side to the horizontal limb of the splint and embracing the posterior aspect of the lower fragment (Fig. 428). As this strap passes around the elbow a smooth, flat, powdered pad of gauze should be interposed between it and the skin. This splint is bandaged to the arm and the arm supported at the wrist by a sling.

If there is much tendency to upward displacement, this may be overcome by hanging a weight of 5 pounds at the angle of the splint. Or downward pressure of the splint against the forearm may be secured by the following

means:—Four adhesive strips, 1.25 cm. (½ inch) wide and 15 or 20 cm. (6 or 8 inches) long, are laid against the front of the upper arm in its upper third and bandaged to the skin to a level about 2.5 cm. (1 inch) below the top of the splint. The upper ends of the strips are left free. The splint is then applied, bandaged to the forearm, and, as it is firmly pressed down, each of the free upper ends of the adhesive strips is taken, drawn over the top of the splint, rotated and made to adhere to the front of the splint. The bandaging of the upper arm is then completed and the lower end of the splint supported in a sling. The forearm against which the splint presses should be well padded with gauze.

In some of these cases, it will be found that the tendency to displacement is forward; here the surgeon must discover the position which will hold the fracture the best; often immobilization with the arm straight gives the best result. This is accomplished by an anterior and posterior straight splint.

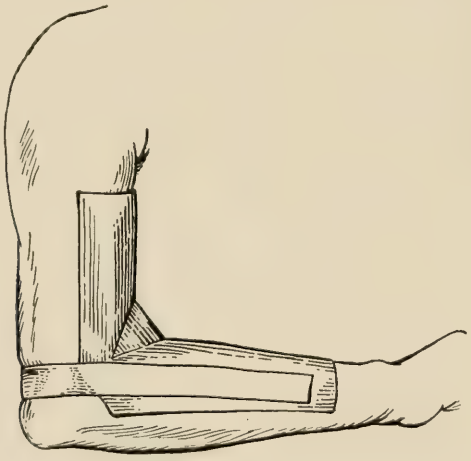


FIG. 428.—RIGHT ANGLE ELBOW SPLINT FOR SUPRACONDYLOID FRACTURE WITH TENDENCY TO POSTERIOR DISPLACEMENT OF LOWER FRAGMENT.

Gauze should be placed between the splint and the skin, the whole should be covered with a bandage, and the forearm supported in a sling.

In other cases the posterior displacement is best overcome by extreme flexion, although there is always danger that this position will tilt too far backward the upper end of the lower fragment.

Fractures of the internal epicondyle require that after reduction, the forearm be supported in the flexed position until union has taken place. A light plaster-of-Paris or other stiff dressing will help to support and protect the part.

Fractures of the external epicondyle may be treated by the application of two oblique, decussating strips of adhesive plaster to make slight pressure upon the fragment. The elbow should be immobilized for two weeks in the straight position.

Fractures of the internal and *external condyles* are oblique fractures with a tendency to upward displacement of the smaller fragments, and usually with posterior or other horizontal displacement or rotation. While every case has its own peculiarities, the method of treatment which is best for the largest number of these fractures is by the position of acute flexion. This position draws forward the lower fragment, presses the coronoid

and soft parts against it in front, presses back the lower end of the upper fragment and makes tense the ligaments and triceps tendon attached to the olecranon.

The arm is put up in acute flexion in the following manner: The bend of the elbow is well powdered and a few layers of gauze laid on to keep the skin surfaces apart. One hand grasps the forearm near the elbow, flexes the elbow and it makes downward traction upon the joint, while the other hand grasps the condyle and presses it downward. The flexion is steadily continued until decided resistance, pain or circulatory disturbance is encountered. Because of the tendency to swelling in these fractures, the sooner treatment can be applied the better. If there is much swelling, flexion should be carried as far as possible, the arm bandaged and the flexion increased as the swelling subsides. A strip of adhesive plaster 5 to 10 cm. (2 to 4 inches)

FIG. 429.—FORCIBLE FLEXION APPLIED TO ELBOW.

Note gauze in bend of elbow, gauze between arm and body, and gauze between adhesive plaster and skin. A broad adhesive plaster strip, applying even pressure, holds elbow flexed.

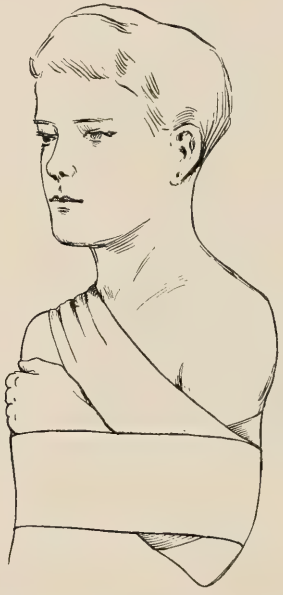


FIG. 430.—COMPRESSION BANDAGE OF ELBOW.

This bandage makes flexion of the elbow, supports the arm, and holds it fixed to the chest.

wide should be passed about the arm as high as possible and include the forearm as low as possible (Fig. 429). The application of this strap is an important step. It should be put on so that it lies smoothly and does not bind at either edge. It is not necessary that the plaster should adhere throughout its whole surface. The skin is spared irritation if a bandage is first applied and then the plaster put on over the bandage, just overlapping the edge to adhere to the skin sufficiently to keep it from slipping downward.

Swelling about the elbow will continue unless slight compression with a bandage is made. This may be done with a flexing bandage of the elbow

(see Bandages, Vol. III); or a compression bandage may be applied (Fig. 430). The latter should be made of three thicknesses of strong muslin and should be nearly as wide as the forearm is long. It begins on the scapula of the injured side, passes across the back to the shoulder of the sound side, forward over the shoulder, obliquely across the front of the chest, between the arm and thorax, around the back and outer side of the arm, around the flexed forearm, between the elbow and the chest, about the arm, obliquely across the front of the chest, over the shoulder, back to the arm, about the arm, forearm and chest, to be pinned back of the axilla of the injured side (Fig. 430).

After the dressing has been applied, the pain should show a tendency to subside, the pulse should be present in the radial artery, and so far as palpation can discover the bony landmarks about the elbow should be in normal relation. If the bandage is too tight it should be loosened. An *x*-ray picture after the dressing is of great value. The dressing should be seen every other day by the surgeon. At the end of ten days or two weeks it should be removed, the bend of the elbow powdered and the dressing reapplied.

Three weeks of this immobilization suffices. At the end of that time the forearm may be carefully brought down to a right angle and carried in a sling. In four weeks union should be fairly firm, and the patient may begin to make some motions. In five weeks the sling may gradually be dispensed with. Passive motion is not of much value in these fractures. The restoration of perfect motion depends upon the perfection of reduction. A good reduction will be followed by good function; in a poor reduction, function will not be helped by passive motion. The patient will gradually develop the fullest possible motion without extraneous aid.

While this treatment by acute flexion is applicable to most cases, some will be discovered not to respond favorably to it. In a certain number of cases a right-angle splint gives the best result. In some, operation and direct fixation must be done. Nail fixation may be used or suturing of the periosteal soft parts often suffices. In these operations, the relation of the ulnar nerve to the back of the inner condyle and of the musculospiral nerve to the front of the external condyle should be borne in mind.

It happens in many of these fractures that motion is limited by excessive callus growing along the line of fracture. Such callus often becomes converted into a bony excrescence which limits motion, and the full function of the joint is not secured until this exostosis is exposed and chiseled off (see Operations on Bones and Joints, page 688).

T-fractures and comminuted fractures of the lower end of the humerus usually require general anesthesia for their reduction. The fragments should be manipulated into place while extension is made in the direction of the long axis of the bone. Immobilization of the elbow at a right angle will usually best meet the conditions; although extreme flexion in some cases and the straight position in others will be found best. A plaster-of-Paris dressing serves best for the right-angle position.

If it is found impossible by manipulation to replace certain fragments, by all means should the well-equipped surgeon cut down upon the bone and correct the displacement. Usually a periosteal suture of chromic catgut will hold these fractures. If the bone can not be satisfactorily replaced it is always best to remove loose fragments. The external condyle is sometimes troublesome and may be removed without fear of serious harm to the joint. Both condyles may be removed and a useful joint secured, provided the olecranon is not damaged and the periosteum with its muscular attachments is left.

Because of the danger of ankylosis in these cases the best possible reduction should be made. The better the correction of the displacements, the less the possibility of ankylosis. If for any reason there is a strong probability of ankylosis, then treatment at an angle slightly greater than a right angle is desirable.

Separation of the lower epiphysis and *low supracondyloid fractures of the humerus* are commonly associated with backward displacement of the lower fragment. Sometimes there is inward displacement. These deformities should be corrected absolutely. Manipulation, traction and flexion will usually reduce the fracture. In some cases reduction by these methods is impossible, in which event the fracture should be exposed and corrected. Such a case is shown in Figs. 219, 220, 221 and 222. In this, neither ligaments nor periosteum were broken posteriorly, the lower fragment being held locked in posterior displacement. I exposed the fracture by a posterior incision, opened the posterior ligament, and replaced the fragment. It then remained in good position irrespective of flexion or extension of the forearm, and a good result was secured. The relation of separation of the epiphysis to future retardation of growth should be explained to parents.

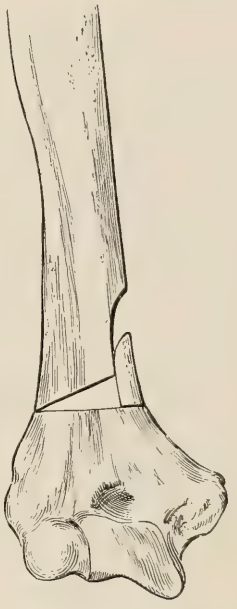


FIG. 431.—TREATMENT TO BE APPLIED TO LOWER END OF HUMERUS TO CORRECT DEFORMITY DUE TO OLD FRACTURE.

By sliding down a fragment of bone healing is hastened.

Fractures of the articular process of the lower end of the humerus include breaking off of the capitellum, of the trochlea, of both articular processes, and comminuted fractures. As no muscles act directly upon these fragments, when once put back in position by manipulation they tend to remain. Immobilization of the elbow at a right angle is the best position, the forearm being supported by a sling at the wrist.

Deformity following fractures of the lower end of the humerus may be immediate or late. Immediate deformity is due to bony displacement and swelling of the soft parts. Later deformity is due to vicious union, exostosis or excessive callus, and trophic disturbances. Deformity due to vicious union may often be improved by operation. Deformity and limitation of motion due to exostosis can almost always be cured by exposing the bony excrescence and removing it. There is a form of trophic deformity which deserves especial consideration. A fracture in a young person involving a part of the epiphyseal line on one side or the other may be reduced nicely, and solid union and a perfect functional result secured. But in the course of time the other side of the bone grows more rapidly because of the premature ossification of the epiphyseal cartilage on the injured side. Thus an obliteration of the "carrying angle" or an increase of the "carrying angle" gradually develops. This irregularity of growth, if the bone has much more length to attain after the injury, may cause a very considerable deformity. After the eighteenth year, when the last of the four ossific centres of the lower end of the bone has united with the shaft, supracondyloid osteotomy may be done, and the retarded condyle lowered (Fig. 431).

Ankylosis following fracture of the lower end of the humerus is not to be feared if good reduction has been secured. Mobilization of the elbow need

not be hastened because of fear of ankylosis. This complication occurs when there is bad reduction, when there is infection of the elbow-joint, and sometimes when the patient is old or is a victim of constitutional infection. Massage in all cases is of service. The treatment of most fractures of the elbow in the position of acute flexion has contributed much toward giving full flexion and extension as a result. This method insures complete flexion; and complete extension is more easily secured than flexion after these injuries.

Fractures of the Radius and Ulna

Fractures of the head and **neck of the radius** are so rare that but little experience in their treatment has been had. Naturally, after manipulation if there is displacement, position will be best maintained with the forearm flexed and semipronated to relax the biceps. A resulting, pronounced limitation in motion of the forearm may be remedied by excision of the head.

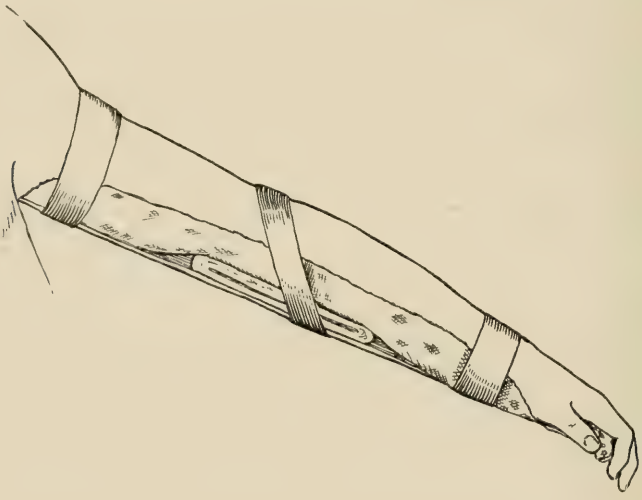


Fig. 432.—Fracture of Olecranon, Treated on Long Straight Splint.
Note padding and oblique adhesive strip to hold down olecranon.

Fractures of the olecranon are analogous to fractures of the patella. The degree of separation is very variable. In some cases not all of the posterior fibers of periosteum and fascia are torn, and there is but slight separation. In these latter cases the elbow may be immobilized with an anterior splint in a position midway between that of extreme extension and right-angle flexion. The position of the elbow may be changed occasionally for the comfort of the patient. This position is not always the most desirable. In some cases full extension will be better, and in other cases full flexion. This must be checked up by *x*-ray examination. The question of operation or no operation is not so important as the question of adhesions. Bony union with joint adhesions is much worse than fibrous union without them. Infection means adhesions. If an aseptic operation is done a good result may be expected.

In most cases there is complete separation, to such a degree that bony union cannot be expected without operation. In the hands of the well-equipped surgeon, a longitudinal incision should be made exposing the frac-

ture. Blood clots should be removed from between the fragments, the skin dissected back a short distance on either side, and, with the arm in the extended position, the fragments should be united with interrupted sutures of chromic catgut. A sufficient hold for these sutures can usually be secured in the periosteum and periosteal fascia; if not, the bone may be drilled in one or both fragments. The overlying skin wound should be closed with a subcuticular suture. This operation should be done with extreme asepsis. The elbow may be immobilized with a slight degree of flexion. Passive motion may be begun in three weeks. Union is firm in four weeks. The arm may be used in six weeks.

The nonoperative treatment of this fracture usually gives fibrous union, but a satisfactory functional result: that is, with free motion but slight limitation at the end of flexion and extension. It is best applied by a straight wooden splint extending from the axilla to the tips of the fingers. The splint should be separated from the arm by a padding of gauze. It should lie along the inner side of the upper arm and the front of the forearm and hand, the hand being in semipronation (Fig. 432). The splint should be attached above and below by oblique adhesive strips. The fragment of the olecranon is then pressed downward and an adhesive strap passed obliquely above it to hold it to the splint. The whole arm and splint are then enveloped in a bandage. The splint should be removed in two or three weeks and the plaster renewed. The splint may be omitted in four weeks. Gradual passive motion is then made for two more weeks, after which the arm may be used. Several months may elapse before the arm has regained its fullest possible function. Extension may never be quite complete.

Malgaigne's hooks or staples are not altogether to be rejected as unsurgical. They have a value standing midway between open operation and the straight splint. With every aseptic care under general or local anesthesia, with the arm in the straight position, a wide staple is driven into the two fragments. A snug dressing is applied and the arm put up on a straight anterior splint. The hooks of Malgaigne are driven into the bone, and then, being connected by a screw, the fragments are approximated by screwing them together. Usually the surgeon who is capable of a safe application of this apparatus is capable of doing an open operation, which is infinitely more satisfactory.

Old cases with fibrous union which has become stretched until function is decidedly impaired are best treated by operation. The fracture is exposed by a longitudinal incision, the skin dissected up, the fibrous material cut away from between the fragments, the bone surfaces freshened with the curette, and the fragments sutured together the same as in the primary operation. Enough fibrous material should be left to make an overlapping flap on one side or the other, as is described in the treatment of fractures of the patella.

Fractures of the coronoid process are best treated by immobilization of the elbow-joint in comfortably acute flexion and strong supination of the forearm. There is but slight danger of ankylosis, and the flexion and immobilization should be maintained undisturbed for four weeks at least; and, if necessary, longer.

Fractures of the shafts of the radius and **ulna** are usually associated with angular deformity. Overriding may require correction in some cases. Reduction is made by grasping the forearm below the fracture and making steady and forcible traction while at the same time pressure is applied to correct the angular displacement. This correction should be made perfect. Splints should be ready to be applied at once. The important thing in the

immobilization is that no pressure by bandage or splint should be made in such a direction as to press the two bones together. The normal distance between the two bones is essential for good pronation and supination. When only one bone is broken, the other acts as a splint, and reduction is more easy and immobilization more secure.

The best immobilization for these fractures, whether involving one or both bones, is made by two stiff boards, somewhat wider than the breadth of the arm (Fig. 433). These should be padded on one side with sheet wadding and smooth gauze, and be applied to the front and back of the semipronated forearm. The splints should extend from just below the elbow to the roots of the fingers. The anterior splint should be cut out so as not to press upon the thumb. Extra padding will be required just above the

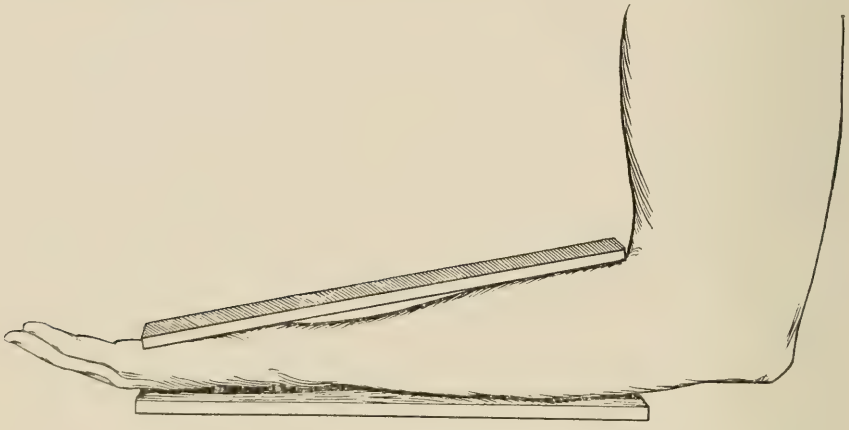


Fig. 433.—Wooden Splints Used in Treatment of Fractures of Forearm. Note hollow above wrist on anterior surface which must be filled witb padding. When this splint is bandaged the thumb should be upward.

wrist anteriorly. The splints should be firmly pressed together and held by three or four circular adhesive strips, while the forearm is flexed with the thumb up (Fig. 434). As this compression is made the muscles are pressed between the two bones; they are also extruded laterally between the splints. It is of the greatest importance that this squeezing out of the muscle should not be hindered by the adhesive strips or bandages, because non-resistance in this direction is necessary for good separation of the two bones. The splints should be wide enough to further this end.

In addition to the forearm splints, immobilization of the elbow should be secured by means of a right-angle anterior splint (Fig. 435). This may be of metal, wood or plaster-of-Paris. Its object is simply to prevent motion at the elbow. Over all of the splints a bandage should be applied and the forearm carried in a triangular sling, at a right angle across the front of the body, with the thumb up (see Bandages). The hand should not be allowed to drop toward the ulnar side, excepting in fractures of the radius alone. To prevent this, an adhesive strip should pass across the palm of the hand and around the posterior splint only. It is doubtful if the longitudinal roll of gauze placed between the two bones by many surgeons is of any service.

In fracture of the *shaft of the ulna* with outward displacement of the lower fragment the hand should be put up in abduction. For fractures of the shaft

of the radius or of the shafts of both bones, a useful position in many cases is with the hand strongly supinated and the forearm flexed on the arm.

Greenstick fractures of the radius and ulna will usually heal in a deformed position unless the bend of the bone is overcorrected or unless the fracture is made complete by bending it still further.

Fractures of the upper part of the shaft of the radius are so prone to irreducible anterior displacement of the fragment operated upon by the biceps muscle, that, if reduction cannot be secured by acute flexion, open operation and suture offers the best hope of a good result.

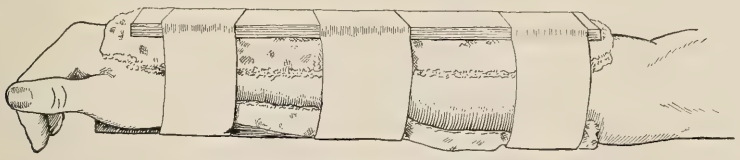


FIG. 434.—FRACTURE OF FOREARM.

Wooden splints padded thickly with gauze, and tightly bound with three broad strips of adhesive plaster. Note that the splints are broad enough so that the adhesive touches but does not strongly press the skin on the radial and ulnar sides of the arm.

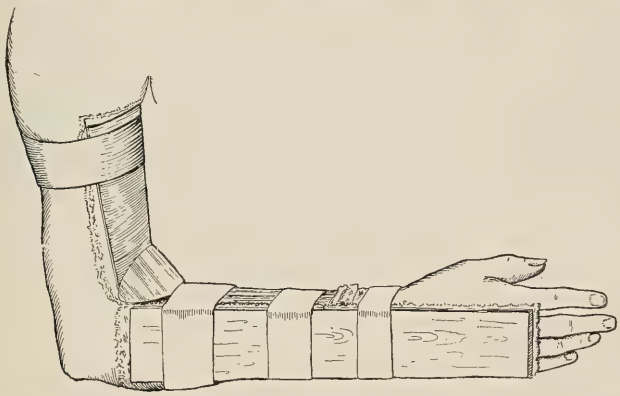


FIG. 35.—RIGHT ANGLE SPLINT APPLIED IN CONJUNCTION WITH FOREARM SPLINTS IN FRACTURE OF FOREARM.

A bandage of muslin should be added to this dressing to cover the entire splint.

Fractures of the forearm require diligent watching. There is a strong tendency to bowing and angular displacement. Ischemic paralysis should also be watched for, and the splints removed and active treatment instituted as soon as it is discovered. The splints should be removed at least once a week and the arm inspected. An *x*-ray picture is of the greatest service. Good apposition and immobilization should be followed by firm union in four weeks. In children, union is strong in three weeks. The arm should not be used until the sixth week.

Fractures of the lower end of the radius are often called after Colles the Irish surgeon who described one of the most common of these lesions. There are a number of different fractures of this region. The common one is the fracture caused by a fall upon the palm, occurring from 1 to 2 cm. (⅓ to ¾ inch) above the articular surface, with posterior displacement of the lower fragment, giving the characteristic, "silver-fork deformity." There may or may not be a breaking off of the styloid process of the ulna. Usually

there is impaction of the fragments with a certain amount of comminution, so that after the best possible reduction has been accomplished the condition of the bone can never be restored to normal. Fortunately an imperfect bony result is not incompatible with a good functional result. In the case of the young, a good result can always be secured; in the old and persons with a chronic tendency to adhesions in their joints and tendon sheaths, the loss of suppleness of the joints and tendons of the wrist and hand may be so great as to impair the usefulness of the hand for months or years after this fracture.

The most important step in the treatment is breaking up of the impaction and then the accomplishment of reduction. Too much emphasis cannot be laid on this statement. Splints and the after-treatment are of minor

FIG. 436.—REDUCING THE COMMON FRACTURE OF LOWER END OF RADIUS.

The surgeon grasps with his left hand the patient's forearm above the fracture; with his right hand he grasps the patient's hand and thus controls the lower fragment. The wrist is strongly drawn downward and adducted to disengage the impaction; then the lower fragment with the wrist is supinated back into place while the left hand fixes the upper fragment, and the thumb presses the lower fragment into place. The hand may be grasped higher and above the thumb.

consequence. Often the fracture can properly be reduced without anesthetic. Often reduction without an anesthetic fails and the surgeon is compelled to inform the patient to that effect and beg to be allowed to give an anesthetic. It is the wisest plan to give a general anesthetic in all cases with deformity unless there are contraindications. The operation can be done under primary ether narcosis; and the patient awakens while the splint is being applied.

The surgeon should grasp the lower end of the upper fragment, that is the forearm, with the left hand; and the wrist and lower fragment with his right hand. His left thumb should press the dorsum of the lower fragment. The lower fragment itself should be in his grasp, the right hand encircling the wrist above the thumb. The first thing is to break up the impaction. This is done by slightly continuing the dorsal flexion, and then making strong traction upon the lower fragment together with flexion of the wrist toward the ulnar side. A rocking motion helps to free the impaction. Sometimes considerable force is required. Usually the fragments easily separate. The surgeon should not be satisfied until he has actually recreated the fracture, and can elicit the sensation of crepitus. The next step is the reduction of the fracture. This is accomplished by continuing the traction and lateral ulnar flexion while pressure with the right thumb is made upon the dorsum of the lower fragment and upon the palmar aspect of the upper

fragment. After reduction is accomplished, forced pronation should be applied to guarantee the forward riding of the lower fragment. All this is easily done by the surgeon with his two hands. In the case of a small arm the hand, instead of the wrist, may be grasped (Fig. 436).

In most cases only slight traction and dorsal pressure upon the lower fragment is required and the bone slips back into place and remains there. It is true that treatment with a snug circular bandage about the wrist will see most cases through to solid union. But in a very considerable proportion of cases there is either an obliquity of the fracture or a rupture of the anterior supports or an interposition of tissue which produces a tendency to posterior displacement. Rarely the fracture falls back into displacement the instant that the dorsal pressure upon the lower fragment is relinquished. It is because of this possibility and because of the desirability of giving good mechanical protection to the broken bone that treatment by splints is to be adopted.

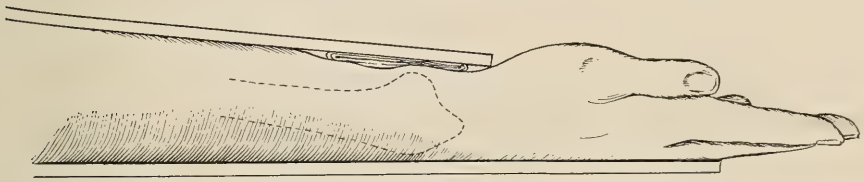


FIG. 437.—DIAGRAM OF SPLINTS TO BE APPLIED TO THE COMMON FRACTURE OF THE LOWER END OF THE RADIUS.

These splints should be padded with gauze the same as the splints shown above in fracture of the forearm.

The fracture having been reduced, a pad of gauze 1 cm. (⅓ inch) thick and 5 cm. (2 inches) square should be placed upon the palmar surface of the lower end of the upper fragment; a similar pad should be placed upon the dorsum of the wrist just below the fracture; and a thicker pad should be placed on the back of the hand to give some flexion of the wrist. These pads should be solid, of flat or tightly rolled gauze and well powdered. They should be held in place by a flannel bandage and adhesive plaster. This bandage should hold the pads and make snug compression around the wrist and lower arm. Two well-padded splints are then applied with the forearm in semisupination, thumb upward. The splints should be of stiff wood, not quite as wide as the upper part of the forearm and slightly wider than the wrist. The posterior splint should reach from just below the elbow to the roots of the fingers; the anterior splint should reach only as far down as the lower end of the radius (Fig. 437). These two splints should be bound together by two or three circular strips of adhesive plaster. A tight roll of gauze 5 or 8 cm. (2 or 3 inches) long should be fitted between each splint at the radial and ulnar side of the fracture and held tightly by the lower adhesive strip. The object of these pads is to make pressure upon the radius and ulna, to prevent the spreading apart of the two, which is so common in this injury. Over all is applied a roller bandage, leaving the thumb and fingers free to move. The hand is permitted to fall in adduction, and the forearm supported flexed at right angle in a sling. Care should be taken that the sling shall not support the hand, the weight of which is of service to continue the traction upon the radius (see Bandages, Vol. III).

The dressing should produce a sense of comfort. The patient should be instructed to report back at once if the ends of the fingers become dark, swollen, or numb, or if pain is severe. He should be seen on the following day. After that the arm should be inspected in a week; and the splint

should be removed at least in ten days for a more careful examination. After the first two days, the patient should be encouraged to move the fingers to prevent tendovaginal adhesions. At the end of the second week the posterior splint should be shortened sufficiently to allow motion at the wrist-joint. At the end of the third week the splints should be removed daily and gentle upward massage applied to the wrist region. In four weeks the bone is strong enough for the splints to be dispensed with, the arm simply being carried in a sling.

L. S. Pilcher (Annals of Surg., 65, 1, 1917) for many years has taught that, in the treatment of this fracture, immobilization by splints has been overdone, and that all indications may be met by the simplest protection after perfect reduction once has been accomplished.

In the large class of cases in which there is little or no tendency to displacement after reduction, a simple plaster-of-Paris case may be put on

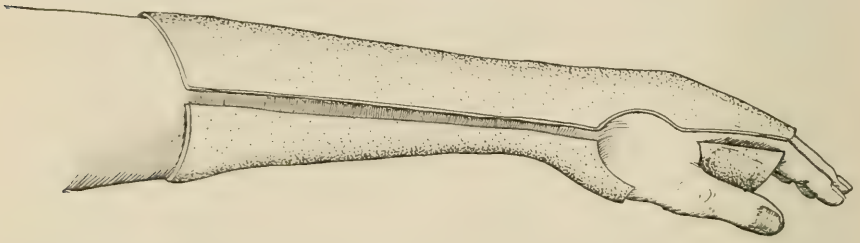


FIG. 438.—COMMON FRACTURE OF LOWER END OF RADIUS TREATED IN A SIMPLE PLASTER-OF-PARIS CASE WHICH HAS BEEN BISECTED TO PERMIT INSPECTION AND REMOVAL.

A muslin bandage should be applied to hold the splint.

without using pads. A bandage of gauze is applied from the middle of the fingers to the elbow. Over this plaster bandages are applied to a thickness of 2 or 3 mm. (1/8 inch). The thumb is left free. While it is hardening correcting pressure is made on the dorsum of the lower fragment and the hand is held in the position of adduction. In this position the splint hardens. Before it is dry it may be cut longitudinally its whole length on the radial side for purposes of later inspection and removal (Fig. 438).

There are many cases in which the splints are not required for more than a week; and there are cases in which the tendency to displacement is so great that the splints must be kept firmly applied until the bone is well united. In the old and in other persons with toxemias, giving rise to a tendency to synovial adhesions, early mobilization and the integrity of the joints and tendons are of more moment than the consideration of the fracture itself. In many such cases the best results will be secured by removing the splints daily and applying massage, passive motion, and hot and cold applications, the splints being dispensed with entirely after a few days. And, in a certain number of these cases, with good reposition and no manifest tendency to displacement, no splint further than a firm circular bandage of flannel or adhesive plaster need be used.

Irreducible displacement may occur in connection with epiphyseal separation or fractures in which a slip of fascia, ligament or tendon prevents reduction. Operation should be done. Usually the fragments remain in good position after being replaced. If the lower fragment tends to slip out it may be held by sutures of the soft parts or by a peg, which should preferably be made of autogenous bone. If a bone peg is used the operation is completed at one sitting: this is naturally the ideal procedure.

Fractures without displacement occur and are recognized by the history, the line of tenderness, the slight swelling, pain and the *x*-ray. They require only a circular bandage to give some protection for a week or so, and abstinence from use.

Vicious union or *imperfect reduction* should be corrected under anesthesia by osteotomy, or, if it is less than two weeks old, by refracture.

Fractures of the lower end of the radius with anterior displacement of the lower fragment require the same principles of treatment as are applied to the characteristic fractures with posterior displacement, the method of correction and applying splints being reversed.

Dislocation fractures and *sprain fractures* may be transverse oblique or longitudinal, and require reduction of the deformity, if there is any, as soon as possible, followed by the general principles of immobilization, rest, passive motion and massage, already laid down.

Fractures of the styloid process of the ulna should be treated by immobilization in ulnar flexion.

Compound fractures of the lower end of the radius should be treated by the methods already described (Compound Fractures, page 518). Amputation should not be done, unless the hand becomes gangrenous. Something can always be done with this important organ even though removal of the lower end of the radius and ulna or of the carpal bones becomes necessary.

Fractures of the Carpus, Metacarpus and Phalanges

Fractures of the carpal bones are not common injuries. The scaphoid, semilunar, cuneiform, pisiform, and os magnum have been found broken. The *x*-ray is invaluable in the treatment of these injuries, and in revealing the cause of "stiff wrist," "weak wrist" and "rheumatism." It should be borne in mind that the scaphoid is sometimes developed in the form of two bones. Displacements of fragments can usually be corrected by extension and pressure. Immobilization of the hand and wrist and the subsequent use of massage, much as in fractures of the lower end of the radius, are called for. When a displaced fragment cannot be replaced by external manipulation, it should be cut down upon and reduced or removed.

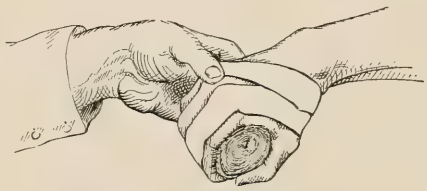


Fig. 439.—Fracture of Second Metacarpal Bone Treated by Fixing Hand about a Roller Bandage with Adhesive Plaster.

Fractures of the metacarpal bones are usually associated with some overriding and angular displacement. Correction is made by grasping the finger, connected with the broken bone, and making traction. A gauze roller bandage of comfortable size, and about 10 cm. (4 inches) wide and 4 cm. (1½ inch) thick, made spindle-shaped by the addition of some gauze around its middle, is placed in the palm of the hand, and the finger drawn strongly over it and held by adhesive plaster. The other fingers naturally flex around the bandage roll. Another strip of adhesive plaster is passed transversely around the bandage and across the dorsum of the broken bone, holding the bandage firmly in the palm and making pressure upon the fracture. If the fracture is not of the first metacarpal bone, the thumb need not be included in the plaster (Fig. 439). Over all a muslin bandage may or may not be applied.

In fractures with overriding too great to be overcome by this treatment or with posterior angulation, a palmar splint should be applied, extending from the middle of the forearm well beyond the finger tips. This splint should be especially padded at the hollow above the wrist. Adhesive strips are placed along the sides of the finger and held by a bandage. These strips are connected to rubber elastic bands which are drawn over the end of the

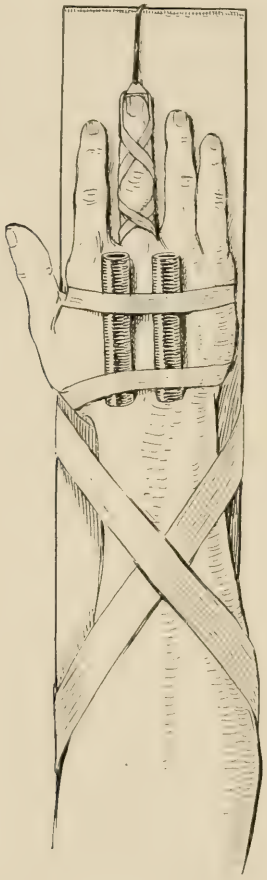


FIG. 440.—FRACTURE OF THIRD METACARPAL BONE WITH OVERRIDING AND LATERAL DISPLACEMENT.

Method of making traction by rubber band, and lateral pressure by rubber tubes. A well-padded firm wooden splint lies on the palmar aspect. Gauze should be placed between the rubber tubes and the skin.

splint and made fast to a peg to make traction. The splint is held by adhesive straps at the wrist and across the hand. To correct lateral displacement a rubber tube on either side of the bone is effective (Fig. 440). A pad anteriorly or posteriorly may be required to make pressure upon one fragment or the other. The traction may be dispensed with in two weeks. Four weeks are required for union.

Fractures of the phalanges require slight traction while a palmar splint is being applied and held with adhesive plaster and bandage (Fig. 441).

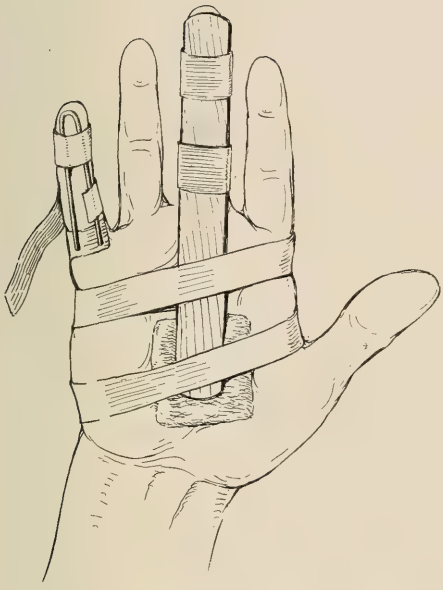


FIG. 441.—FRACTURE OF PHALANGES.
Wooden splint applied to middle finger; wire splint (hairpin) applied to little finger.

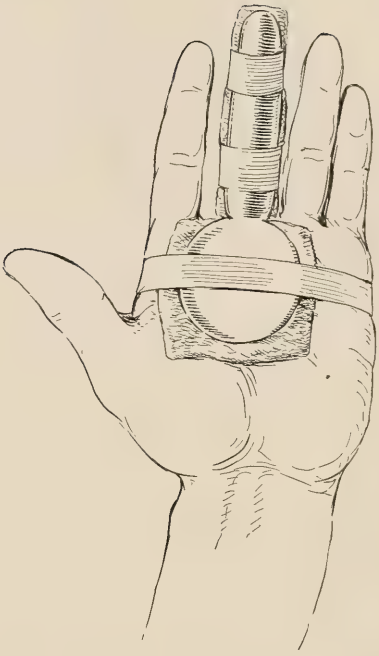


FIG. 442.—FRACTURE OF PHALANX.
Splint of pliable metal. Gauze should be placed between splint and skin.

FIG. 443.—FRACTURE OF PHALANX OF THUMB.
Wooden splint held by adhesive strip. A padding of gauze should be placed between splint and skin.

These splints may be made of wood, aluminum, tin (Fig. 442), paper, or wire.

In some cases a smooth gauze padding may be placed on either side and the broken finger bandaged to the two adjacent fingers. *Fractures of the thumb* may be treated with a palmar splint (Fig. 443). A valuable splint may be made of tin to fit the angle between the thumb and index-finger (Fig. 444).

Fractures of the proximal phalanx sometimes present angular displacement or overriding which is best treated either by a roller bandage in the palm or by a long palmar splint and traction as is applied to metacarpal fractures.

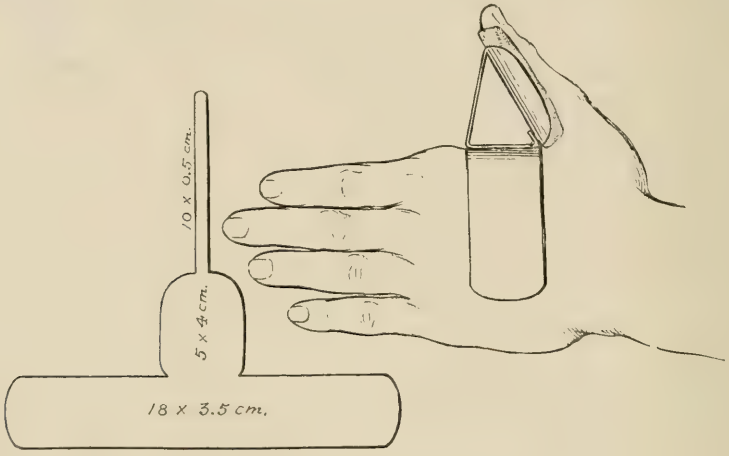


FIG. 444.—THUMB SPLINT OF GOLDTHWAIT.
This splint is made of tin, and is bent to fit the thumb and hand. Gauze should be placed under it. It is held with adhesive strips and bandage.

Compound fractures are important because of the dangers inherent in infection of the tendon sheaths. Such a fracture, which is going to result in a stiff finger at the best, was formerly treated by amputation—excepting in the case of the thumb which was always preserved however badly damaged. Now, with the modern possibilities of arthroplasty, the creation of new joints and the restoration of destroyed joints always holds out hope of restoration.

Fracture of the sesamoid bone of the thumb, situated at the palmar side of the first metacarpophalangeal joint, should be diagnosed, and then treated by immobilization in slight flexion for four or five weeks.

FRACTURES OF THE PELVIS

Fractures of the pelvis are not uncommon injuries, and previous to the use of the *x*-ray they were not discovered or treated in the majority of cases. They are so often associated with rupture of the bladder, urethra, kidney, intestine or iliac veins, that these conditions should be looked for; and when found they usually are of more importance than the fracture itself. These visceral injuries should receive the first consideration.

Fractures of the wings of the ilium are best treated by rest in bed in the recumbent position. Fractures through the pelvic ring, as seen in fractures of the pubes, require the support of a tight, encircling, adhesive plaster band. Comminuted fractures and fractures with deformity sometimes require

operative reposition of the fragments. In some cases continuous extension upon the thigh is necessary, as in fracture of the acetabulum. In others immobilization of the hip by a long side splint is called for if it is found that a fragment moves with the femur. The Bradford frame and the water-bed will often contribute to the comfort and ease of handling these patients. Fractures of the sacrum and coccyx are rare, and require reduction and quiet. Fractures of the pelvis heal in four weeks.

Fractures of the Femur

Supracervical fractures of the great trochanter are usually held in place by some untorn fibres of periosteum and fascia. When separation is present, rest in bed with the thigh in abduction is called for. Great separation may require operative exposure and suture or pinning of the fragments.

Fracture of the lesser trochanter may be treated by immobilizing the thigh in the position of flexion and inward rotation.

Subcervical fractures of the great trochanter may be transverse or oblique. The important point is that they separate the neck from the shaft of the femur. They are not uncommon fractures. They require traction and immobilization; the same as fractures of the neck.

Fractures of the head of the femur are rare. When associated with dislocation, the latter becomes the more important injury. After reduction of the dislocation, immobilization with traction is called for.

Fracture of the neck of the femur has been met by a great variety of treatments. Bad results have been very common until the combined traction method was more generally adopted within the last few years.

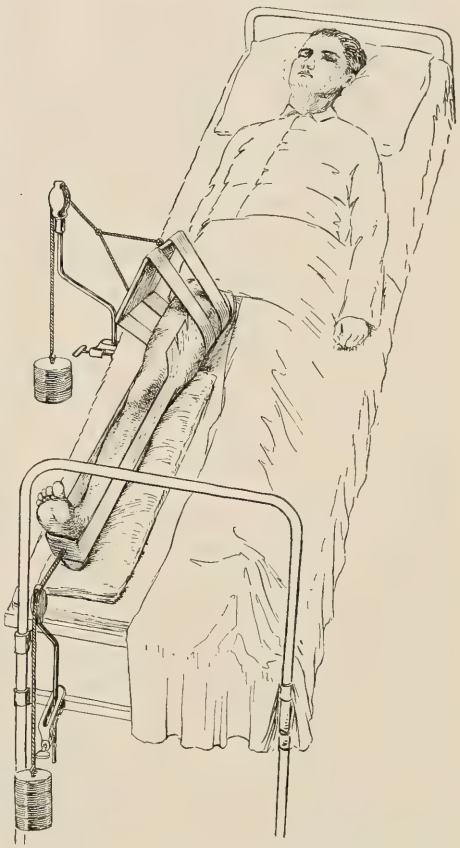


Fig. 445.—Fracture of Neck of Femur.

Treatment by lateral and longitudinal traction. The foot of the bed and the side corresponding with the injured leg are elevated.

In *fractures without impaction*, or following the breaking of impaction with malposition, the effective treatment is by *combined longitudinal* and *transverse traction*. This method is that used and described by G. W. Phillips (Am. Jour. Med. Sci., 1869) and more recently perfected and popularized by C. E. Ruth (Albany Med. Annals, Jan., 1913). The neck of the femur being broken, the psoas-iliacus muscle, which normally is an internal rotator of the thigh, becomes an external rotator. External rotation, flattening of the hip, and shortening are the deformities to be overcome. Longitudinal traction should

be provided by adhesive strips attached to the full length of the thigh but not below the knee. These strips are connected over a pulley to a weight at the foot of the bed. A spreader should be placed below the foot to prevent pressure of the straps upon the malleoli (see Traction Treatment, page 487). It is not necessary to use splints of any kind nor the car and track apparatus. The leg should simply rest on a pillow, extending from the thigh to the heel. The heel should be free from pressure. For the lateral traction a piece of binder's board, 10 cm. (4 inches) wide, is smoothly padded on one side with gauze, especially about the edges. This should be long enough to reach two-thirds around the extreme upper part of the thigh, leaving the outer third of the circumference uncovered. It should be made fast with two broad strips of adhesive plaster, encircling the thigh. A third piece of adhesive plaster, 8 or 10 cm. (3 or 4 inches) wide, is passed about the middle of the paper-board and the two ends carried toward the side of the bed for traction purposes. These two ends are passed over a spreader capable of spreading them slightly more than the diameter of the thigh. To the two ends of the spreader a cord is attached, each of which passes to a single cord which passes over a pulley to the traction weight (Fig. 445).

The lateral traction should be made outward, slightly upward, and forward: outward to overcome the crushing deformity, upward so that it shall not be overcome by the longitudinal traction, and forward to overcome the gravity displacement of the lower fragment. The object of the spreader is to prevent pressure on too much of the circumference of the thigh and especially on the internal saphenous vein. Without it swelling of the leg will occur. It also serves to secure leverage for rotating the limb. By shortening the cord to the lower end of the spreader, external rotation is corrected. The foot should be directed a little external to the vertical position.

Before applying the weights the fracture should be reduced. The thigh should be flexed on the body while an assistant grasps the upper part of the thigh and makes traction outward. This outward traction is continued while the surgeon makes longitudinal traction and extends the thigh until it lies horizontally on the bed. The two tractions are maintained until the weights have been attached. From 20 to 30 pounds longitudinal pull is desirable and about two-thirds of that for the lateral pull. The amount of traction should not be any arbitrary weight but enough to overcome shortening of the limb and flattening of the hip. The foot and side of the bed should be elevated so that the patient is not pulled out of the middle of the bed. The lateral pulley should be about opposite the waist and somewhat anterior to the body.

This treatment relieves pain and makes the patient comfortable. The patient may be moved easily. The bed-pan is used without difficulty. The patient may be elevated to the sitting position for a daily rubbing of the back. Older persons should be required to sit up in bed several hours a day. The apparatus is kept on for six weeks in most cases; but after the first ten days the amount of traction is gradually reduced, until by the end of four weeks there remains only enough weight to make gentle traction and keep the patient quiet. At the end of six weeks the patient is allowed to sit up in a bed with no weights. At the end of seven or eight weeks he may sit up in a chair and go about on crutches. Weight may now be borne on the toes but it is best not to require the femur to carry weight until the end of eight or ten weeks. Some surgeons allow the patients on crutches at the end of six weeks.

This treatment should be applied as soon after the accident as possible. It is immaterial to the technic whether the fracture is intracapsular or

extracapsular or both. The only part of the apparatus which the surgeon must supply and which cannot be found in any farm house is the adhesive plaster. Spools may be used for pulleys and bags of sand for weights. Good results have been secured in cases which have gone two weeks without treatment. Cases are reported in which good results have been obtained after seven weeks of non-union.

No treatment is used which compares with this method. It makes the treatment of this injury simple and comfortable. Union may be expected in every case. The aged need not be confined more than four weeks, after which they may sit up most of the time. If they have vitality to survive that long, they will be found to have vitality enough to heal the fracture.

The *abduction method* of treating non-impacted fractures in adults, next to the method of double traction, is to be recommended. A splint of wood or plaster holds the thigh immobilized in extreme abduction.

Impacted fracture of the neck of the femur, if the position is fairly good, should not be disturbed; but if there is much deformity or much external rotation the impaction should be broken up and combined traction applied. In a recent fracture impaction may be broken up under general anesthesia by forcible lateral traction. As an assistant holds the pelvis on one side the surgeon grasps the thigh at the perineum and pulls outward, the limb being pulled downward by a second assistant. A rocking or jerking motion may be necessary. In old impactions, the joint must be opened by anterior arthrotomy and the fracture reproduced with chisel or saw.

Impaction is a common complication of fracture of the neck. When it is present, and the position is not bad, immobilization with some extension is the treatment of choice. In many cases, extension of 10 pounds will suffice to give the necessary immobilization. Extension is demanded in all cases with shortening of more than 2 cm. (¾ inch). The extension is applied by adhesive strips of moleskin along the inner and outer sides of the thigh, connected by a weight and pulley at the foot of the bed (see Traction in Fractures, page 487). The foot should be covered with a cotton stocking and rest simply on a pillow. Sand-bags may be placed at the sides of the leg to steady it and prevent rotation. A persistent tendency to rotation may be overcome by placing the leg and foot upon a car or by making rotary lateral traction. The bed should have a solid mattress resting upon slats or board.

The use of plaster-of-Paris casing for these patients is unnecessarily cumbersome and confining. A long side splint, reaching from the axilla to beyond the foot and having a T-piece at the lower end to prevent rotation is of service. This is bandaged to the trunk and leg as in fractures of the shaft, and may be used in connection with extension; or in some cases with weak muscles and little danger of displacement, the extension may be omitted.

The wire splint of Hodgen is very satisfactory. It consists in a rod passing down either side of the leg and joined below the sole of the foot. A gutter or sling is made by weaving a bandage from one side to the other. The leg is laid in the splint and elevated just free of the bed by ropes attached to the splint, and passing off in a downward direction in such a way as to make traction (page 488). The leg is prevented from sliding by the slight flexion at the knee.

After two or three weeks a Thomas' hip splint may be applied (Fig. 446). In fact, this splint may often be used from the beginning. It is one of the most satisfactory appliances for injuries and diseases of the hip, in these cases of impacted cervical fracture. It is made of soft iron and has riveted to it three bands of similar material to embrace the chest, pelvis, thigh and calf. The main shaft is 3 cm. (1¼ inch) wide and 1 cm. (¼ inch) thick,

and should reach from the level of the axilla to below the middle of the leg. It is curved so as to conform to the back and buttock and made to lie just to one side of the spine. The three bands are made of metal 2 mm. ($\frac{1}{16}$ inch) thick, and should fall short of encircling the part to which they are applied. The thigh band should come well up to the perineum. The chest band should have an opening in either end to receive a strap. The splint is padded with felt on the inside and covered with soft leather. This splint is put on, the bands are compressed to fit the part, a bandage is applied to the leg and thigh, and a band of muslin to the chest. Shoulder straps or suspenders may also be attached when the splint is to be used on an ambulant patient. For the recumbent patient traction may or may not be used. One of the advantages of this splint is that it permits the use of the bed pan and turning the patient without fear of disturbing the fracture. The skin should be pulled from one side to the other daily to prevent continuous pressure upon one place. As much padding as is required may be placed between the splint and the skin.

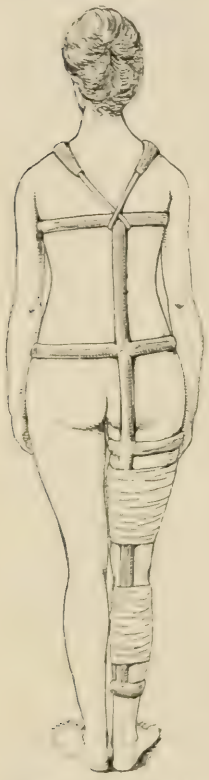


FIG. 446.—HIP SPLINT OF THOMAS, USED IN THE TREATMENT OF FRACTURES OF THE FEMUR.

Later, with a lift under the sound foot, the patient may go about with crutches. This splint is useful also in fractures of the shaft after the patient is allowed up but union is not firm.

Fracture of the neck of the femur in the aged is of special importance because of the dangers of shock and hypostatic pneumonia. An old person with a broken hip should be an object of special solicitude. Every attention should be given to nursing, to the light and airiness of the room, and to cheerful surroundings. The patient should be spared fatigue both physical and mental. The food should be simple and nourishing. To prevent pneumonia the patient should be kept out of doors or in a well-aired room. The apparatus should not confine the body too much. Fractures without impaction should be treated by the method of longitudinal and lateral traction, described above. In exceptional cases of extremely feeble persons no pressure or traction can be tolerated. But in most cases, even of the very feeble, the patient will be more comfortable and have a better chance of ultimate recovery, with the two tractions. In such cases but little weight should be used. In the cases with impaction, in very feeble persons, it is best to place the limb in the most comfortable position, steady it with pillows or sand bags, overcome outward rotation as much as can be done with comfort, and give more consideration to the patient than to the fracture. Exercises of the lungs, taking deep breaths for a certain number of times, at certain hours of the day, will do much to prevent pneumonia. Upon the first appearance of pulmonary congestion the patient should be gotten to sit erect. Indeed, it is good treatment to have these old people lie with their shoulders elevated from the beginning.

The *time required for union* in fractures of the neck of the femur is variable. Eight weeks should be given to whatever treatment is adopted before union can be expected to be solid. The patient should remain in bed for two or four weeks after the apparatus is removed, unless there is some in-

dication to the contrary. Then he may sit in a chair or go about on crutches with a lift under the sound foot.

The *operative treatment* of fractures of the neck is called for especially in young persons, in whom union has not been secured. Under guidance of the *x*-ray, a peg is driven through the neck and into the inner fragment. This method is sometimes indicated in the cases of adults. If the displaced head cannot be manipulated into position, the well-equipped surgeon may open the joint and proceed with the reduction. If a foreign body, like a nail, is driven into the bone, it is best that the patient should not know it, else he attribute his pain to it.

The joint is opened by the anterior incision beginning above just below the anterior superior spine of the ilium, and curving downward and inward. The sartorius is retracted inward. The capsule is exposed and the fracture felt before the joint is opened. The joint being opened, retractors are introduced and direct observation made. The blood should be sponged from the joint, and the displaced head rotated into position with instruments rather than with the fingers. The leg is then placed in the position in which the fragments lie best together. In recent fractures this will usually be found to be in extreme abduction of the thigh. The leg is now held in this position. A small punctured wound is then made 4 or 5 cm. (1½ or 2 inches) below the tip of the great trochanter and a nail, 8 cm. (3¼ inches) long, in the case of an adult, is driven through the bone in the direction of the long axis of the middle of the neck, into the head. The nail is driven in until the head passes below the level of the skin by means of a nail set or another nail.

If a small wire nail is used the bone need not be drilled, but if a nail or peg of large size is employed the bone should be drilled for the nail. If there is a tendency toward rotation of the head, two nails should be used. The wounds are closed, and a plaster-of-Paris case applied from the toes to the level of the nipples, holding the limb in abduction. If an iron nail has been used, it should be removed after consolidation.

Metal pins, driven in bone, cause absorption of the bone around the pin. For this reason the ideal pin is of bone. This does not cause rarefaction of bone; it is a permanent source of strength; no secondary operation has to be done to remove it; and it is less prone to invite infection. If the surgeon is equipped to introduce an autogenous bone peg, this is the most satisfactory operative method (see page 514).

Fractures of the neck of the femur in childhood are often of the green-stick variety. Frequently these fractures are not recognized or are treated for some other disease. Treatment is of importance because of the danger of coxa vara and adduction of the thigh. These cases should be recognized early by the elevation of the trochanter and other symptoms, and treatment applied. Ordinarily in children the best treatment is that advocated by R. Whitman. The thigh is fixed in extreme abduction, by means of a plaster-of-Paris case from the toes to the axillæ, or by an angular wooden or metal splint lying along the outer side of the limb and the axillary line of the body. Cases with mobility of the fragments at the fracture are best treated by the double traction method as in the adult. After four weeks, the child may be allowed up with a hip-splint, giving immobilization and slight traction. A lift should be put under the well leg and the child allowed on crutches after the sixth week. The injured side should not be used if there is any pain, and at least not before eight or ten weeks of immobilization.

When deformity has resulted from coxa vara and adduction of the shaft, the condition may be improved by subtrochanteric osteotomy and putting

up the new-made fracture in plaster-of-Paris with the thigh abducted (see Coxa Vara, Vol. III).

Fractures of the shaft of the femur are among the most difficult of all fractures to treat. A perfect anatomical result is rare. This is because these fractures are usually oblique, and the unresisted contractile power of the thigh muscles is so great that overriding of the fragments is an almost insurmountable difficulty. The ordinary treatment gives union and an ultimately strong leg, but usually shortening and bony distortion are concomitant therewith. Moreover, if the surgeon attempts to prevent the shortening by open operation, he finds that, even with the bone ends exposed, the shortening can but rarely be overcome. We must be satisfied to reduce the shortening as much as possible, to see that there is true alignment of the bone, to prevent rotation, and to immobilize the fragments until consolidation is secured (see General Principles of Treatment of Fractures, page 472). Shortening of 2.5 cm. (1 inch) or less is compensated for by the tilting of the pelvis, and need not cause a limp.

Fractures of the thigh occur usually at some distance from the place where a permanent dressing is to be put on, and for safe transportation a *temporary splint* should be applied. This should consist of well-padded pieces of board 1 cm. (¼ inch) thick and 10 cm. (4 inches) wide. One should be placed posteriorly from the top of the pelvis to the middle of the calf; another should be on the outer side from the axilla to the sole of the foot; an anterior piece should reach from the groin to the patella; and a shorter piece should be placed on the inner side of the thigh from the crotch to the condyle. For padding these splints, cotton, towels or other soft material may be used. A pad should be placed under the knee to give slight flexion. Traction should be made upon the leg, and the lower fragment rotated until the foot points forward. Two or three straps, or a bandage, about the thigh will fix the splints. The leg should be bandaged to the long side splint below, the malleolus being well padded; and a broad band of muslin about the chest will hold the upper end. With this dressing the patient may be carried comfortably to the place where he is to be confined for the further treatment.

For the *permanent dressing* the patient should be placed upon a narrow bed having a firm mattress, resting upon boards. Before removing the temporary splint everything should be in readiness for the permanent dressing. A general anesthetic will be of much aid to the surgeon and comfort to the patient. For the sake of example an oblique fracture in the middle of the shaft may be considered.

The temporary splints should be removed. The most perfect reduction possible should be made by traction and manipulation. The leg should then be held in strong traction by an assistant while the dressing is applied (see Method of Applying Traction, page 487).

The amount of weight to be used for traction in fracture of the femur is a difficult problem. Briefly, it should be all the patient will stand. The important thing is that the weight should be applied as soon after the receipt of the injury as possible. Surgery should recognize fracture of the shaft of the femur, with its inevitable overriding, as entitled to serious emergency consideration. An adult male will stand a weight of 30 or 40, or even 60 pounds. Unfortunately, in some cases, not even these weights will completely correct the defect. The greatest weight possible should be used for the first week. After that it may be reduced weekly until the end of the third week, when 15 pounds of extension are enough. Ten or 15 pounds longitudinal extension should be continued during the fifth week. Lateral or transverse

displacements are best met by transverse traction. For this purpose a weight of not more than 8 to 12 pounds is necessary (page 583).

It is always wise to cut out that part of the adhesive strap which lies against the head and neck of the fibula, in order to avoid pressure on the perineal nerve. Neglect to do this, especially when heavy weights are used, may result in paralysis of the nerve and the "foot drop" which is not uncommonly seen in these cases.

By the end of the sixth or seventh week there should be *consolidation*. The extension apparatus may be removed in the sixth week, and the splints continued for a week or two longer. If good consolidation is found at the end of the seventh week, a plaster-of-Paris splint or wooden splints, reaching from the knee to the top of the pelvis, may be applied, and the patient allowed about on crutches with a lift of 6 cm. (2½ inches) under the shoe of the opposite foot. Some sort of splint should be used to support the bone at least until the end of eight weeks. By the end of the tenth week weight may be borne on the leg.

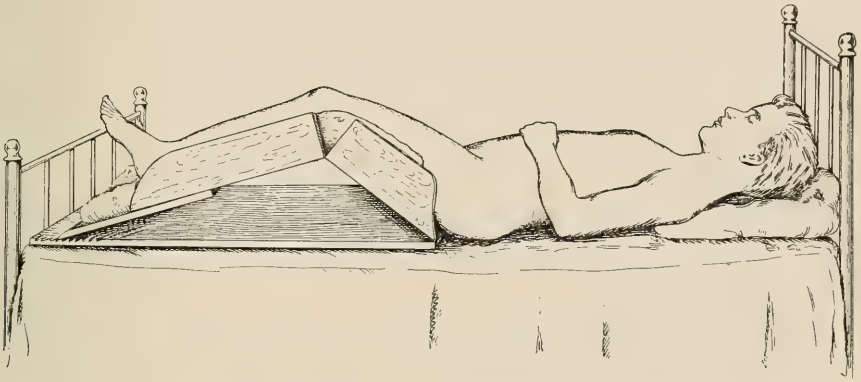


FIG. 447.—DOUBLE INCLINED PLANE IN TREATMENT OF FRACTURE OF FEMUR WITH TENDENCY TO FORWARD DISPLACEMENT OF UPPER FRAGMENT.

The limb should be inspected frequently during the course of treatment. It should be comfortable. The tendency for the patient to be pulled down by the extension, if not entirely overcome by raising the foot of the bed, may be met by placing a small wooden box in the bed against which the foot of the sound leg may push, and a folded sheet may be carried obliquely from the crotch to one of the bed posts at night. When the extension apparatus is removed the leg should be washed and powdered.

If when the traction is removed the union is soft and the fracture capable of being bent, a plaster case from the ankle up to the top of the pelvis may be put on, and, with a lift under the other shoe, the patient allowed about on crutches. Or the hip splint of Thomas may be used (Fig. 446). Delayed union, if still present at the end of the third or fourth month, calls for operative treatment (see Delayed Union, page 527). Following this the leg may be put up in the splints already described, without the extension, and treated as a recent fracture.

Variations from the usual in the treatment of these fractures are often encountered. Difficulties in reduction may be due to comminution or to multiple fractures, and require manipulation or open operation for their correction. In these cases the *x*-ray is a valuable aid. In oblique fractures a sharp end of fragment may pierce the muscle and become so firmly engaged

that its release is only possible by open operation. A sharp point of the lower end of the upper fragment is sometimes best dealt with by pushing it on through the skin and cutting it off.

Fractures in the upper part of the shaft are apt to be associated with abduction of the upper fragment. This is best met by using a long side splint which reaches only as high as the waist, and putting up the whole leg with extension in the abducted position. Flexion of the upper fragment is also found in these cases; in which event the flexion may be overcome by the pressure of the anterior splint, or the limb may be put up on a single or double incline plane (Fig. 447), or in vertical extension. These latter expedients usually become necessary in children (Fig. 448). A single inclined plane is often useful in the cases of children (Fig. 449).

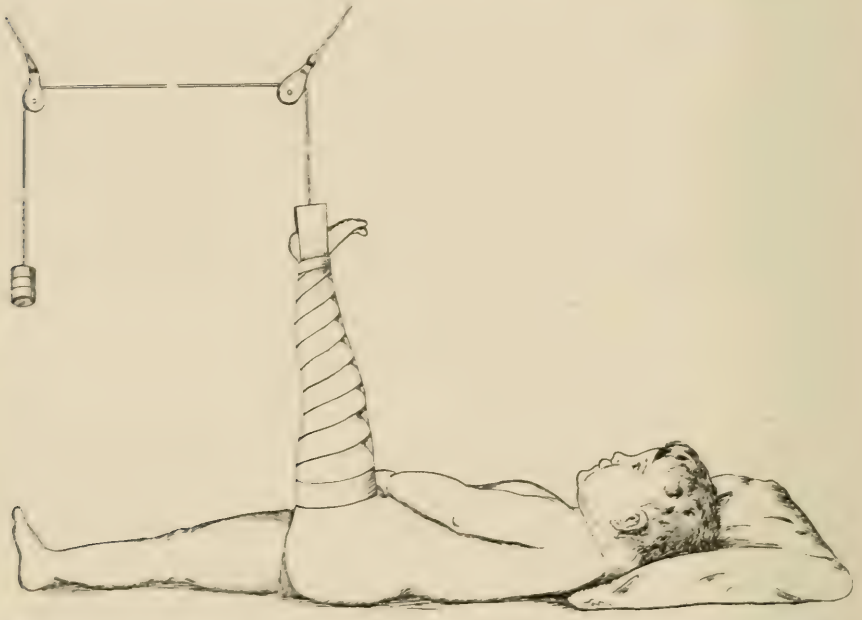


FIG. 448.—VERTICAL TRACTION AS USED IN TREATMENT OF FRACTURE OF FEMUR IN CHILDREN OR IN ADULTS WITH ANTERIOR DISPLACEMENT OF UPPER FRAGMENT.

Transverse fractures of the shaft of the femur are the exception in adults. In children they are more commonly encountered. A strong adult with such a fracture has an injury which is practically incurable without lateral displacement equal to the diameter of the bone unless open operation is done. To put the fragments end-to-end requires operative exposure of the bones, and even then reduction of the fracture is often impossible unless the bone is shortened by sawing off the end of one or both of the fragments. This is one of the subjects not much touched upon in the treatment of fractures, and I have only my own experience to guide me. I hope that there may be surgeons who have succeeded better than I in effecting reduction of transverse fractures of the shaft of the femur in strong men, without sacrificing some of the length of the bone. Happily, even with this overriding and lateral displacement, union is secured; and, aside from the slight inconvenience of shortening, a good functional result is obtained.

In children reduction may be accomplished by flexing the hip and knee and making strong traction In many cases it is impossible. Treatment by vertical extension is most satisfactory in the cases of children.

The *operative treatment* of fractures of the shaft is best carried out through a liberal longitudinal incision on the outer side of the thigh. Here are no important structures; and the operation consists in opening the deep fascia and making a blunt separation of the muscle down the fracture. The bone ends are made to present in the wound and are dealt with as necessary (see Operative Treatment of Fractures, page 502).

The *suspension splint* (page 487) may be used in patients with fracture of the shaft to whom it is desirable to give the greatest comfort and the least restraint. This splint is an elongated U, made of iron, the curve passing

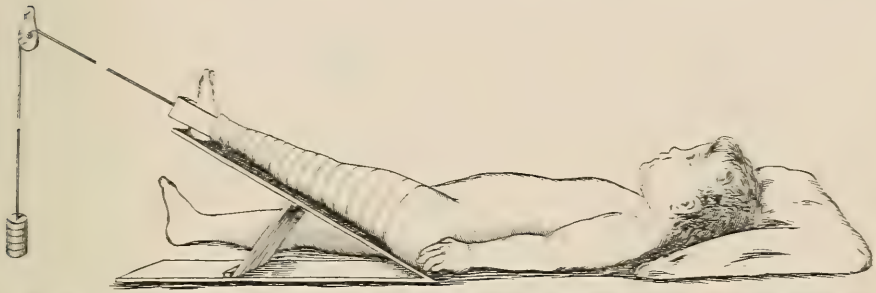


FIG. 449.—SINGLE INCLINED PLANE WITH TRACTION IN TREATMENT OF FRACTURE OF FEMUR WITH TENDENCY TO FORWARD DISPLACEMENT OF UPPER FRAGMENT.
The back of the limb should be well padded and the foot of the bed slightly elevated.

below the sole of the foot, and the side arms lying along the side of the limb. It should be bent slightly at the knee to give slight flexion. Roller bandage is passed back and forth to make a bed in which the limb lies. Suspension cords swing the apparatus to a crane above the bed. It does not secure perfect immobilization, but this seems not essential for union. There is apt to be more shortening than follows treatment by weight extension. A combination of this splint with extension has much to recommend it. The adhesive strips, as for ordinary traction, are applied to the limb, and connected with the weight at the foot of the bed. The limb is suspended, and traction is made at the same time. This method gives much comfort to the patient; the fragments are better controlled; and the patient is not so bound to the bed. Counterextension may be made if necessary by elevating the foot of the bed, or by passing a sheet below the patient's perineum. It is highly convenient for the patient to have a crane for lifting himself by the arms, and a box at the foot of the bed against which the sound foot may be pressed.

The *plaster-of-Paris* case may be preferred in some cases, the whole lower extremity and the pelvis being encased while traction is made. If a firm padding is applied and the plaster is made firm and tight against the tuberosity of the ischium and perineum, the foot below and these points above supply the purchase necessary to maintain extension. In applying the plaster the patient is supported upon a pelvic supporter and extension and counter-extension are made.

Hip splints such as are employed in the treatment of tuberculosis of the hip lend themselves especially to the later treatment, but in some cases they may be used to advantage in the early treatment either with weight and

pulley extension or elastic extension connected to the lower end of the splint. For this purpose the hip splint of Taylor is used.

Compound fractures may be treated in the usual extension apparatus, the splints and adhesive plaster being applied so as to avoid the wound. If the wound is large or much dressing is required, a plaster-of-Paris splint, encasing the lower extremity up to the groin, giving flexion of the hip and knee, and being suspended by cords to a horizontal rail, is satisfactory. A fenestrum allows dressing without disturbing the splints on the patient. The double inclined plane also is useful in these injuries. A splint of plaster may be applied with traction. It should embrace the pelvis and the foot. A fenestrum may be cut before the plaster is dry (Fig. 450).

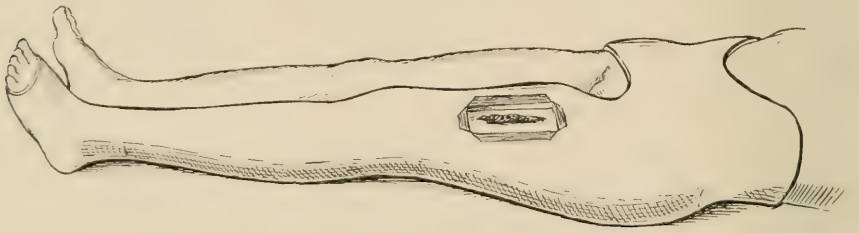


FIG. 450.—PLASTER-OF-PARIS SPLINT IN COMPOUND FRACTURE OF THIGH WITH WINDOW FOR DRESSING WOUND.

This splint will hold a fracture which has been united by operation.

In *young children* fractures of the shaft are best treated in *vertical extension* (Fig. 448). To properly confine a young child, both limbs should be so treated. The extension is applied with adhesive strips and a spreader at the foot just as in the adult (page 490). From each foot the cord passes up over a pulley arranged so as to give some abduction and right-angle flexion of each thigh. The cords may be made fast to weights just sufficient to lift the child's pelvis free of the bed. Children who are amenable to reason

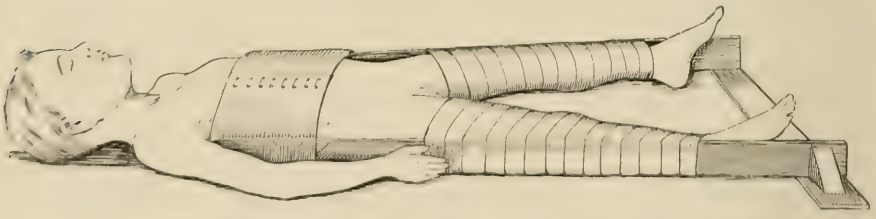


FIG. 451.—DOUBLE LATERAL SPLINT FOR TREATMENT OF FRACTURE OF FEMUR IN CHILDREN.

A thick padding of gauze should be placed between the splint and the skin.

and will remain fairly quiet are best treated by extension only of the injured thigh. This adds the advantage of giving abduction as well as flexion. Coaptation splints should be placed about the thigh. In the very young they may be covered with rubber protective.

Another satisfactory method is by the *double lateral splint*. This consists simply of two side splints, reaching from the crest of the ilium to a point well below the soles of the feet. The lower ends of the two splints are connected by a crosspiece somewhat longer than the width of the pelvis so that the legs are well abducted (Fig. 451). This splint immobilized the child's lower extremities, and the abduction allows free access for diapers and cleans-

ing and at the same time corrects a very common tendency of abduction of the upper fragment. By covering the dressings with oiled muslin or other impervious material they may be kept dry. Fractures in the *newborn* are best treated by splints or abdominal flexion (see page 530).

Union in children is firm in three or four weeks. Children over nine years of age may be treated in horizontal extension. Plaster-of-Paris encasing of the extremity and pelvis is often of service.

Fractures of the lower end of the femur are the most serious injuries of the femur. Fractures obliquely through the articular extremity, detaching one or the other of the condyles, T-fractures and Y-fractures, all are associated with traumatic inflammation of the knee-joint and the danger of ankylosis. Correction in most cases is secured by manipulation. Ex-

FIG. 452.—METHOD OF REDUCING FRACTURE OF THE LOWER END OF FEMUR SUGGESTED BY H. GIFFORD.

The pelvis is held down by a strong bandage, and with the leg and thigh flexed, traction is applied to the lower fragment through the pull of a rope and tackle applied to the sole of the foot.

tension is of little service. The limb is best put up in flexion, unless some other position is indicated to meet peculiar conditions. A plaster-of-Paris case extending from the toes to the groin, and which is cut into an anterior and posterior half by lateral bisection, is a good splint. The double inclined plane also is used. In some fractures, involving both condyles, it is necessary to apply traction to the leg in order to prevent the fragments from being pressed up by the tibia. Injury to the popliteal vessels may demand operation (see page 437).

An oblique fracture, separating one condyle, is best reduced by placing the leg in the extended position and making lateral flexion, thus using the lateral ligament to pull the condyle into position. The limb is then put up in the corrected position with the knee extended.

The expedient of H. Gifford (Annals of Surg., September, 1915) for the reduction of fractures of the lower end of the femur is most useful. The knee is strongly flexed, under general anesthetic traction apparatus is fixed to the leg, and the pull, made upward toward the knee, thus pulling downward upon the lower femoral fragment (Fig. 452). If the fracture is a transverse one fixation of the knee in strong flexion will hold it (Fig. 453).

Separation of the lower epiphysis of the femur occurs before the twenty-fifth year, and is usually associated with forward displacement of the epiphysis. In a large proportion of cases the epiphysis is hyperextended until it lies on the front of the shaft with its fractured surface looking backward. To correct this displacement, traction upon the leg, flexion at the knee, and pressure downward and backward upon the fragment, under general narcosis, are required. Fig. 454 shows one of the author's cases. The flexion is carried to an acute angle, and the leg and thigh put up in plaster-of-Paris. After two or three weeks the angle of flexion may be gradually enlarged.

FIG. 453.—METHOD OF FIXATION OF TRANSVERSE FRACTURE OF LOWER END OF FEMUR AFTER REDUCTION.

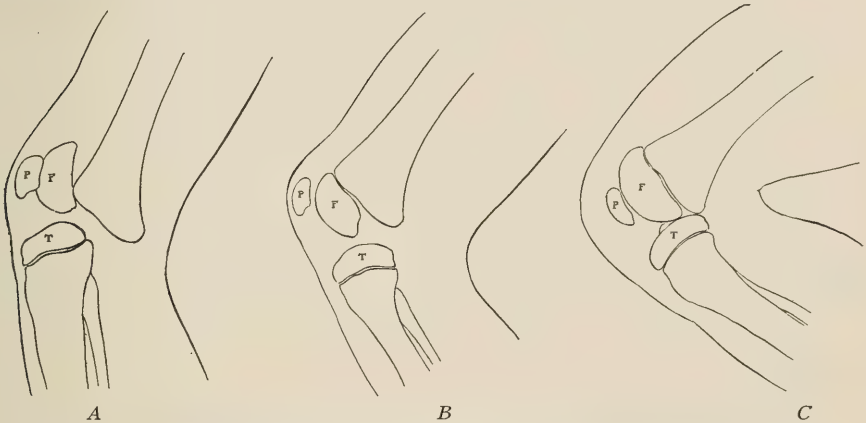
If the fracture is a transverse one, strong flexion of the knee suffices to hold the fragments in apposition.

It happens in some cases that despite every effort reduction cannot be accomplished; in which event reduction may be made by exposing the lesion through an incision on the outer side of the leg, engaging each fractured surface with a strong hook, and pulling one down and the other up until they slip into place. Suturing of the periosteum and fascia with stout chromic catgut will hold them together. As a last resort, after operative exposure, if reduction cannot be affected, resection of a bit of the end of the shaft may be necessary.

In compound fractures, the wound may be enlarged and the epiphysis sutured in place. Damage to the popliteal vessels inflicted by the upper fragment may demand operation on the vessels or amputation.

Fractures of the lower part of the shaft and *supracondyloid fractures* are often difficult injuries to manage on account of the posterior displacement of the upper end of the lower fragment because of the strong contractile power of the gastrocnemius muscle. They must be treated with the knee flexed. If the fracture is high enough to give room for attachment of the adhesive

traction strips extension may be used in connection with the *double inclined plane*. In low fractures there is not enough distance between the fracture and the joint for the adhesive strips. In these cases immobilization in a position of flexion sufficient to put the fragments in alignment is required. The degree of flexion necessary will vary from an obtuse to a right angle, or even to an acute angle. If the flexion required makes an angle of less degrees than a right angle a plaster-of-Paris case, reaching from the lower part of the leg to the hip, may be applied. While this is being put on, extension upon the lower fragment is made at the same time that flexion is maintained. The limb is then supported on an inclined plane, or by a rope run over a pulley. If the latter method is used the rope should be attached to the plaster case just above the knee. Division of the tendo Achillis may be required.



A *B* *C*

FIG. 454.—TREATMENT OF SEPARATION OF LOWER EPIPHYSIS OF FEMUR BY TRACTION AND FORCIBLE FLEXION.

A, Slight flexion shows bad position; *B*, flexion at right angle gives improvement of position; *C*, strong flexion of knee gives perfect correction; *P*, patella; *F*, lower epiphysis of femur; *T*, upper epiphysis of tibia. Tracing of *x*-ray of case treated by author.

A special danger of these low fractures is *injury of the popliteal blood-vessels*. The lower fragment may compress to the degree of occlusion, it may wound to the degree of causing thrombosis, or it may lacerate the vein or even the artery. Correction of the displacement is first called for. If but one vessel is occluded the treatment of the fracture should be supplemented by that for threatened gangrene. If both vessels are occluded amputation at the fracture was until recently regarded as the correct surgical procedure. Now the well-equipped surgeon should cut down upon the fracture and the injured vessels. The fracture should be united by pegs or plates; clots should be removed from the vessels if they are still occluded; wounds of the vessels should be sutured; and the circulation restored (see Operative Treatment of Fracture, page 502; Thrombosis and Embolism, page 454; Gangrene, page 315). Amputation is necessary if the vessels are not operated upon successfully.

Gangrene of the leg, following these injuries, may be either dry or moist. The former, indicating occlusion of the artery, does not constitute an emergency, and time may be given for the appearance of a line of demarcation. But the occlusion of the vein, giving rise to edema, hemorrhagic injection, and gangrene, calls for amputation at once. These conditions should be prevented by recognizing their early signs and operating upon the fracture and the vessels before the irretrievable damage has been done.

Fractures of the Patella

In treating fractures of the patella it should be borne in mind that the patella is a sesamoid bone, developed in a tendon, and that the rupture of the tendon, not the fracture of the bone, is the important injury. The union of the tendon is the object toward which surgery should be directed. The characteristic injury is due to the contractile force of the quadriceps extensor muscles, cracking the patella transversely across the lower end of the femur, tearing the continuation of the quadriceps tendon which lies in front of the bone, rupturing its lateral reflections which pass off from the sides of the patella, causing more or less separation of the fragments and their attached structures, and infiltrating the surrounding tissues and the knee-joint with blood from the wounded structures. The stretched-out and torn tendon and fascia drop down over the fractured surface on one or both fragments, and prevent bony union unless it is removed.

The first requisite in treatment is to check the bleeding and prevent any further damage. This is done by immobilizing the joint upon a posterior splint and applying gentle pressure to the knee. The posterior splint should reach from the upper part of the thigh to the lower part of the leg; a pad 4 or 5 cm. (1½ or 2 inches) thick should be placed back of the knee to give slight flexion; the splint should be bandaged to the leg and thigh; a pad of gauze should be laid on the patella; over the patella and the joint a flannel or tricot bandage should be applied to make even pressure to control effusion; and the limb should be elevated 30 cm. (12 inches) at the foot. This constitutes the temporary or emergency treatment. The choice of methods of treatment is the next step. There are two: the nonoperative and the operative.

The **nonoperative treatment** cannot be expected to give bony union. It is free from danger. In the majority of cases a functional result can be secured which is satisfactory to the patient. Full extension and flexion and a supple joint are commonly attained. In other cases, flexion and extension are not complete, the patient has a limp, there is a sense of insecurity, and joint pains are at times present. Fibrous union never shortens, but there is a tendency for it to stretch. Usually after the first year there is no further elongation. Properly applied the nonoperative treatment may in nearly all cases be expected to give a strong and useful leg, especially in persons not performing heavy work. Much longer time must be given to treatment than after the operative method, although the actual period of confinement in bed need not be greater. The technic is as follows:

The limb is covered with a cotton stocking or a drawer leg. Over this is applied a plaster-of-Paris case (see page 477) from just above the ankle to the upper part of the thigh. This is cut down to the skin on either side with a sharp scalpel while it is still soft, or with a saw later after it is hard, and the anterior half lifted off. So that it shall fit snugly, 1 cm. (⅓ inch) is cut away from each edge of this cover. The edges of each half are bound with a strip of adhesive plaster. The drawer leg or stocking is left adherent to the inside of the two splints. The anterior splint is laid aside. The leg is left resting in the posterior half, to which it is fixed by adhesive strips above and below. The foot is then elevated, and the fragments of the patella are drawn together by strips of adhesive plaster 3 or 4 cm. (1½ inches) wide. Two strips are applied obliquely, decussating across the bottom of the lower fragment, and passing upward and backward to be attached to the splint. The upper fragment is then strongly pressed downward against the lower fragment, and held by strips passed obliquely above it, crossing it, and carried downward and backward to be made fast to the splint. These last

two strips should be connected to the splint by rubber elastic bands which may be held to the splint with adhesive plaster (Fig. 455). A bandage may be applied above and below, leaving the knee exposed; or the anterior half of the splint may be put on and held with a bandage.

If there is still effusion and swelling the fractured edges of the bone will tend to be tilted forward. This is prevented by a bandage or adhesive strip, holding a pad firmly pressed against the broken bone. It is customary to apply massage to the quadriceps muscles. This is unnecessary, as the weakness of the muscle is a desirable thing. Massage cannot be applied with satisfaction to the knee on account of the apparatus.

If the plaster becomes detached it should be renewed. If the skin becomes sore, a bandage, with the turns above the patella making downward pressure, may be applied. At the end of a month or six weeks the fragments need no longer be held together; the apparatus may be removed, the limb put up in a light plaster case to prevent flexion of the knee, and the patient

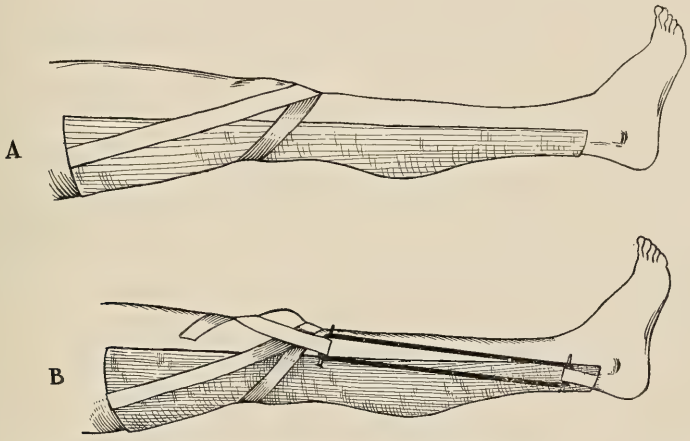


FIG. 455.—FRACTURE OF PATELLA TREATED BY ELASTIC TRACTION AND POSTERIOR SPLINT.

A, Posterior plaster-of-Paris splint and first adhesive plaster strips; *B*, second adhesive plaster strips connected to posterior splint by rubber elastic bands. A bandage is applied over all.

allowed to go about on crutches. The weakness of the quadriceps muscle prevents damage to the fibrous union. This splint may be bisected and removed daily for massage of the knee and muscles. Two months after the accident the splint may be left off when the patient goes to bed, but it should be worn during the day during the third month. By the end of this time some passive flexion of the knee should be made. After the third month the patient may go about with a cane, but a splint, to prevent use of the quadriceps muscles, should be worn until the end of the fourth month. During the first twelve months no sudden action of the knee should be made and no great strain should be put upon the extensor tendon.

The **ambulant treatment** allows the patient to be about with a crutch or cane. Instead of carrying the prepatellar adhesive strips from the skin to the splint, the traction may be confined entirely to the limb without involving the splint. This is done by applying two broad adhesive strips to the front half of the thigh from the upper third down to the top of the patella. These strips should end in a loop. A slipper should be placed on the foot, and below it a broad adhesive strip also ending in a loop. Elastic

bands or rubber tubing then connect the adhesive strips on either side of the leg. These bands should be strong enough to draw down the upper fragment. The posterior half of the plaster splint may be used in connection with this apparatus (Fig. 456). Instead of using the posterior half of the plaster splint, a light case may be applied from the perineum to the middle of the leg, a fenestrum cut in front of the knee, and the two loops brought out through it. The elastic bands are then connected outside of the plaster case. With such a splint as this the patient may walk about.

Another method for the ambulant treatment may be carried out as follows:—A strip of adhesive plaster, as employed in the extension treatment of fractures (page 490), is placed on the inner side of the thigh and another on the outer side. These strips should be about 8 cm. (3 inches) wide above and 4 cm. (1½ inches) wide below. They should be attached to the skin from the junction of the upper and middle thirds down to the level of the upper fragment. A button should be sewed on the lower ends, or the lower

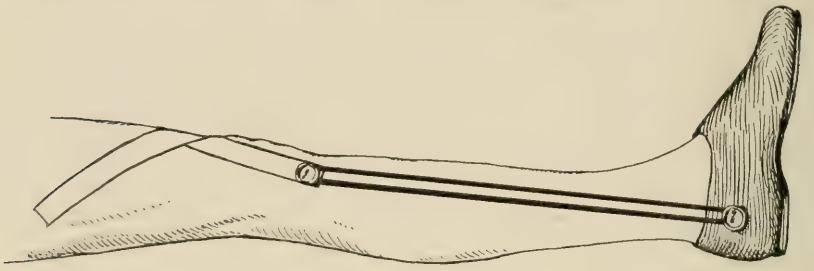


FIG. 456.—FRACTURE OF PATELLA TREATED BY ELASTIC TRACTION, EMPLOYING ADHESIVE STRAPS, RUBBER ELASTIC BANDS, AND A SLIPPER.

A bandage about the knee should be added to press backward the fragments. A posterior splint should be applied to prevent flexion of the knee.

end of the strips should be folded back to make a loop. A few oblique strips, passing across the front of the thigh, should securely fasten these straps to the skin. The limb is then covered with a long stocking, drawer leg, or flannel bandage from the ankle to the perineum. A flat pad of gauze is placed just below and in front of the lower fragment. A plaster-of-Paris case is then applied from the ankle to the level of the perineum, the knee being flexed slightly short of full extension. The splint should be very light but reinforced behind the knee with a piece of bass wood. A fenestrum should then be cut out in front of the knee, extending from the upper border of the lower fragment to the upper border of the upper fragment, and exposing the two loops of adhesive plaster on either side. A loop of adhesive plaster is fastened to the lower end of the plaster case on either side after the case has become dry, and a heavy piece of rubber elastic band inserted in the loops on either side to make traction. A pad of gauze is bandaged in the fenestrum to make gentle pressure on the fragments, and the patient is allowed to be about with crutches or canes (Fig. 457).

The **operative treatment,** suturing together the fragments by open operation, is capable of giving a perfect result. It is the ideal treatment. The objection to its application is, that, in the event of infection, there may result stiffness of the joint, loss of the limb, or death. I have seen all of these results follow operation in the hands of other surgeons. Although simple, it is one of the most serious operations in surgery. Infection in the joint associated with this fracture requires radical measures; free in-

cision and drainage of the joint are essential; wide laying open of the joint may be required; this not availing to control the sepsis, amputation is called for; and these may fail to save the life of the patient. The operative treatment of fracture of the patella should be used only by surgeons of thorough training and skill, who have at their command an operating room and experienced assistants for the performance of aseptic work, and who, in all of the details of environment, nurses, assistants and materials, can command a dependable technic. The operation should not be attempted by the occasional surgeon nor by the surgeon who has not absolute control of his operative environment.

If there is any operation in which the use of rubber gloves is imperative it is in this. It is best that the naked hand should touch nothing that comes in contact with the wound. It is customary to apply preliminary immobilization and compression or cold until the primary swelling has subsided. I have not followed this rule but have operated at the earliest convenience after the injury, usually on the following day. As soon as the patient is admitted into the hospital the leg is washed with soap and warm water, the knee and adjacent parts of the thigh and leg shaved, the skin cleansed with alcohol, the joint enveloped in a copious protective compress, and the whole bandaged to a posterior splint. An *x*-ray picture is taken. When the patient comes upon the operating table, the skin is painted with tincture of iodin from the middle of the thigh to the middle of the leg, in front and behind, and the operation proceeded with. If iodin or its equivalent is not to be used the skin should be cleansed with water and soft soap, followed by acid bichloride alcohol. Some surgeons combine both of these methods.

A median incision through the skin is made, 10 or 12 cm. (4¼ inches) long; or a curved incision with its convexity downward, the lower limit of the incision lying at the lower border of the lower fragment. A fresh knife is taken and the fracture exposed. The superficial fascia is dissected up until the whole extent of the torn structures is exposed. The curled-in ligament is lifted off of the fractured surfaces. A method which I described in 1910 (Trans. Brooklyn Surg. Soc.; Long Island Med. Jour., 1910) and which I have used with much satisfaction is as follows: Usually the torn ligament hanging from the front edge of one fragment will be found longer than that attached to the other. The upper fragment generally has the longer flap. This is carefully lifted up, and its ragged edge trimmed, leaving it as long as possible. The torn ligament on the other fragment is trimmed flush with the fractured surface. The clots are then scraped from the fracture surfaces with scissors, free clots in the joint are sponged out or washed out with warm saline solution. A suture of two strands of

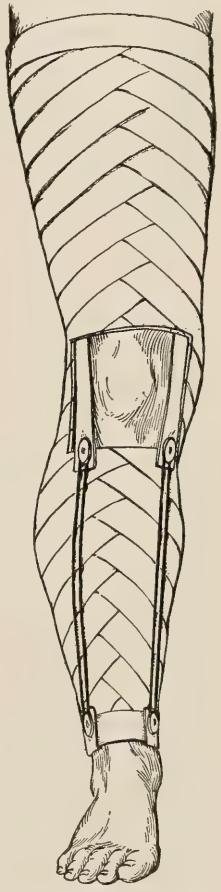


FIG. 457.—FRACTURE OF PATELLA TREATED BY A PLASTER-OF-PARIS CASE COMBINING ELASTIC TRACTION.

The adhesive strips emerge through a window in the case and are connected to rubber elastic bands which make traction.

No. 2, twenty-day, chromic catgut is then passed through the torn ligament at one side of the bone, taking a deep hold, close to the bone. A similar suture is passed on the other side. A final removal of blood from between the fragments is made, the surfaces nicely approximated, and the two lateral sutures tied. These sutures should be introduced about 1 cm. (⅓ inch) from each fracture surface, so that when they are tied they embrace 2 cm. (⅔ inch) of tissue. After they are tied it should be observed that the bone is held in firm apposition. If it is not, the sutures should be supplemented by sutures placed still more widely from the wound.

The next step in the operation consists in suturing the cut-short ligament to the base of the long end on the other fragment. The flap is then

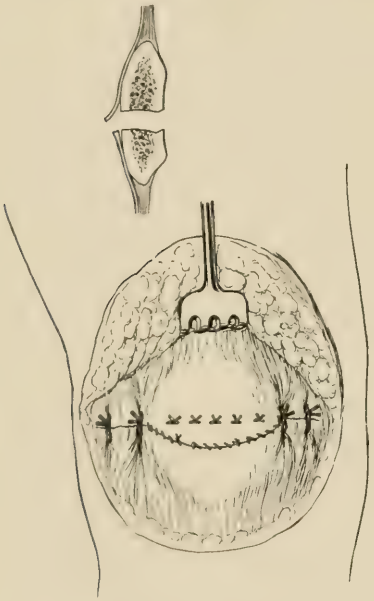


FIG. 458.—FRACTURE OF PATELLA.

Sutures completed. Two deep sutures on either side have closed the lateral tears. An interrupted suture has connected the short flap to the base of the long flap in front of the patella. The long flap has been sutured to the front of the lower fragment by a running suture.

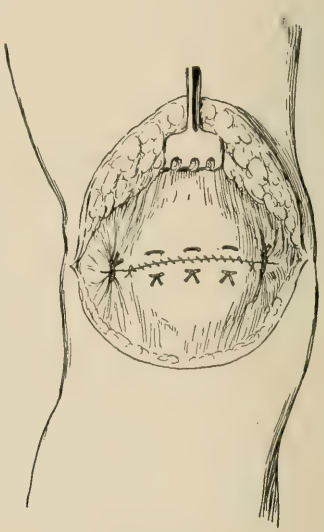


FIG. 459.—FRACTURE OF PATELLA.

Simple interrupted mattress suture and a continuous running suture used when no fascia flap is present.

sutured down in front of the other fragment. No. 1 chromic catgut is used for these sutures. The lateral rents in the capsule and lateral fascia should be closed (Fig. 458).

While the operation is progressing, the parts not being operated upon should be kept covered. If no flap can be secured, the bones are united by interrupted sutures inserted transversely in the prepatellar fascia tendon (Fig. 459). I have never been guilty of the surgical offense of wiring the patella.

The superficial layer of the deep fascia is then sewed the length of the skin wound with a running catgut suture, and the skin closed with a subcuticular suture. A dressing of dry gauze is applied, and the knee immobilized by a posterior splint. This splint should be well padded and comfortable,

reaching from the upper part of the thigh to the lower part of the leg, and have between it and the knee sufficient padding to give slight flexion. A bandage from the toes up should be applied and the patient put to bed with the foot elevated about 25 cm. (10 inches) to relax the quadriceps extensor muscles.

Formerly it was my practice to apply early passive motion and massage. I now believe that, after an aseptic operation, there is no danger of ankylosing adhesions, unless toxic or irritating matter is conveyed to the joint by the blood. In a healthy individual, with healthy tonsils, sound teeth and no other foci of sepsis, such infection is not apt to occur. As to the atrophy of the extensor muscles, it is a salutary process. The primary dressing may be removed in two weeks, and a fresh dressing applied. At the end of the fourth week, the patella may be moved from side to side, and slight flexion of the joint made. General massage of the knee should be instituted

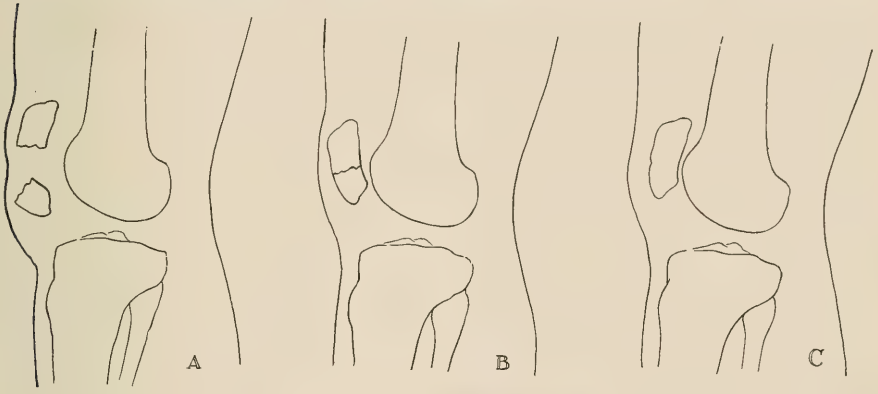


FIG. 460.—FRACTURE OF PATELLA.

Typical case. *A*, Before operation; *B*, immediately after operation; *C*, one year after operation. Tracing made from *x*-ray pictures of one of the author's cases. $\frac{1}{10}$

by the fourth or fifth week; and a bisected plaster case applied and the patient allowed to go about with a cane. It is immaterial what the patient does so long as he does not use his quadriceps muscles; and this end is best secured by keeping the leg straight in a splint. After the fourth or fifth week massage and slight passive flexion should be practised daily until the end of the third month, at which time it may be assumed that the union is firm, and splints may be dispensed with.

In my earlier cases I used massage and passive motion after the tenth day, and allowed the patients to go without splints at the end of six weeks. The results were as good as in the cases longer confined, with the exception that in some cases there was more postoperative hypertrophy of the patella. This I am inclined to interpret as due to imperfect immobilization, a phenomenon to be observed in any fracture not well immobilized.

I have applied the above operative technic to all fractures of the patella to which operation was applicable. In all cases, a perfect result has been secured. Normal flexion and extension have been secured; normal sense of security and strength of knee have been obtained; and in most cases, by the end of a year, the only sign of injury present has been the scar of operation. A slight hypertrophy of the patella is sometimes present, although function is apparently perfect (Fig. 460). In no case have I ever had infection; and in most of my cases I did not wear gloves, although my assistants did.

Refracture occurred twice in one case. When we recall that without operation bony union would have been impossible in these cases, and that the fragments would have been connected by a stretchable band of scar tissue, the reason for designating this operation as the ideal treatment is evident.

Other methods of treatment, which are supposed to stand midway between the nonoperative and the operative treatment, are to be mentioned only to be condemned. Passing a subcutaneous or anteroposterior ligature or wire around both fragments and tightening it; the hooks of Malgaigne, and their many modifications; pegs inserted into the fragments and drawn together with wires and clamps—all of these possess either the dangers of operation or the disadvantages of non-operative treatment. Most of them possess both.

The treatment by *bone-grafting* is most worthy of consideration especially in old fractures (see page 516). Fascia-grafting is to be preferred.

Operative treatment of old cases is often called for because of disability due to stretching of the fibrous union or because of fixation of the fragments. The exposure may be made by a longitudinal median incision or by the curved incision. If the fragments will come together, an operation similar to that described for recent fractures may be done. The bone surfaces are freshened by the knife or rongeur, a flap is left on the upper fragment, and this is sutured over the lower fragment. An adherent upper fragment requires to be loosened from the front of the femur. If there is loss of flexion, either the upper fragment or both fragments may require to be removed (see Operations on Joints, and Operations for Strengthening Patella).

Approximation may be helped by chiseling loose the tubercle of the tibia and allowing it to slide upward to become reattached to bone exposed for the purpose. The upper fragment may be brought down by lifting it away from the femur, and dissecting free from the latter the capsule, muscle and fascia as far up as is necessary. In a case with separation of 9 cm. (3½ inches), I was able to effect approximation by dividing the quadriceps muscles transversely, and bridging the gap with fascia. If the separation is too great for union the upper fragment may be removed and a plastic operation done to shorten and strengthen the stretched tendon. A flap of fascia may be turned down from the quadriceps tendon, sutured over the lower fragment, and lateral approximation of the gap made. The difficulty has been met by detaching the sartorius muscle from its insertion below, and inserting it into the front of the fragments (Schanz). I have done this operation with fair success in one case.

Comminuted and multiple fractures of the patella should receive treatment according to the separation of the prepatellar ligament. If there is transverse division of the ligament, the treatment should be applied as for the ordinary transverse fracture. These cases sometimes present laterally displaced fragments which can only be held in place by suture. My own practice is to expose these fractures, replace the fragments and suture them together through their prepatellar ligament.

Fractures with slight separation, in which there is no laceration of the lateral structures, need receive only the nonoperative treatment. I have recently treated a fracture in which no separation could be felt, but in which very slight lateral motion and crepitus could be elicited. Such fractures require immobilization for two months until union has been secured, and then a posterior splint for a month or two longer for safety. Vertical fractures and fractures producing an anterior and a posterior fragment require immobilization for a shorter time.

Compound fractures of the patella require all of the aseptic care described for the treatment of compound fractures (page 518) and wounds of joints (page 654), together with the operative treatment above described. The wound is best treated with chlorin or iodin. If infective matter has entered the joint, it should be well irrigated with salt solution, especial care should be taken to cut away ragged pieces of fascia and other tissue, the fragments should be sutured together, and drainage on either side should be provided. If there has been much soiling of the joint, posterior drainage also should be provided.

Fractures of the Tibia and Fibula

Fractures of the upper end of the tibia are so variable in character that no specific treatment can be laid down. Oblique fractures of the head, running into the knee-joint, are characterized by a tendency to angulation of the leg in the direction of the fracture, with sliding down of the upper fragment. Usually this can be overcome by placing the leg in its normal position and holding it with a plaster-of-Paris case. Sometimes these fractures are multiple and involve both sides of the head of the tibia, and require extension as well as an immobilizing splint. The first splint applied should be regarded as temporary. Inspection should be made after the joint swelling has subsided. Synovitis may require especial attention. Often lateral pressure upon a fragment will be required to keep it in place. This can be made with a well-powdered pad of gauze under the splint. In most of these fractures the knee should be immobilized with the limb straight.

Separation of the upper epiphysis of the tibia usually shows but little displacement; it is easily put in good position and held with a plaster-of-Paris splint. When there is injury to the vessels, the same rules apply as are given for fractures of the lower end of the femur.

Avulsion of the tubercle of the tibia is treated by extending the leg upon a posterior splint, flexing the thigh, pressing the tubercle down into place and holding it with adhesive strips. The knee should be kept immobilized in this way for five or six weeks. The quadriceps extensor muscles should not be used for two months. If the fragment can not be held satisfactorily in this way, or is rotated and cannot be replaced, open operation may be done and the periosteum sutured. A separated tubercle with nonunion may be united by freshening the bone surfaces and sewing it in place with sutures of chromic catgut through the soft parts. A still more certain method is to bore a hole through the upper part of the tubercle and into the tibia and fasten it with a peg of bone taken from the shaft of the tibia.

Fracture of the upper end of the fibula is treated by correcting the displacement, if there is any, by pressure, and immobilizing the knee and leg with a plaster-of-Paris or other splint until union is secured. The splint should prevent adduction of the leg. With a lift under the sound foot, the patient may go about with crutches. If there is much tendency to displacement the biceps muscle may be relaxed by immobilizing the knee in the flexed position. Damage to the peroneal nerve should be looked for and guarded against.

Fractures of the shafts of the tibia and fibula represent the common fractures of the leg, and will be treated together. These are the fractures which are discussed under the general treatment of fractures (page 47 2, and which are cited as examples. Commonly, fractures of the tibia are oblique, and overriding. Traction is required for their reduction. But unless the traction is continued for at least two weeks, the overriding will recur. In the transverse fractures it is different; it is only necessary to

correct any displacement that is present and provide against lateral or angular deformity. Comminuted and multiple fractures require manipulation as well as traction.

It is my own practice to put up these fractures in a thin plaster-of-Paris case as soon as seen, applying the plaster bandage next to the skin or with a cotton stocking intervening, while the leg is held by a skilled assistant who

FIG. 461.—POSTERIOR GUTTER SPLINT OF VOLKMANN.

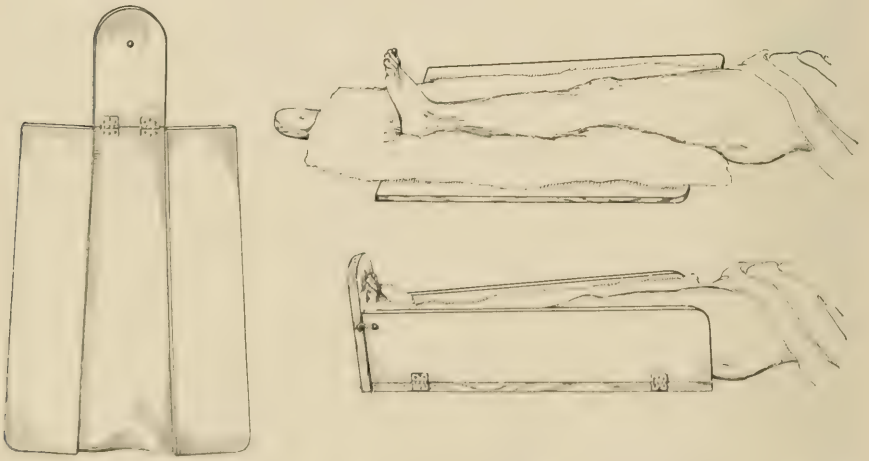


FIG. 462.—FRACTURE-BOX FOR TEMPORARY TREATMENT OF FRACTURES OF THE LEG. A pillow or a mass of padding is placed about the limb and the sides of the box closed upon it to hold the leg snugly and comfortably.

makes traction and maintains a corrected position of the fragments (page 477). The bony prominences of the knee, and the foot at a right angle, furnish the resistance to the plaster case which prevents overriding. This is not perfect, because traction usually does not wholly overcome the shortening; and when traction is released there is still some sliding back. In the ordinary case of oblique fracture, some shortening of the leg is to be expected. The plaster case should be thin and should extend from the

toes to the middle of the thigh. Care should not only be given to preventing lateral displacement, but especially anterior displacement of the lower end of the upper fragment. If there is any question as to the degree of inversion or eversion of the lower fragment, it is always wise to err on the side of inversion. The slightest eversion may mean later flatfoot. To be on the safe side the foot should be inverted at the ankle in putting up the fracture. For safety, if there is danger from swelling, the case may be cut down the middle in front allowing expansion of the leg. It may be held together by adhesive strips or not, as may be required.

It is not to be advised that immediate immobilization in plaster-of-Paris be adopted as the general treatment. As a working rule, it is safer to apply a temporary dressing for one or two weeks until the danger of primary swelling has passed. For this purpose may be employed a plaster case, put on over a layer of cotton wadding, a well-padded posterior metal splint (Volkmann) (Fig. 461), the fracture box (Fig. 462), splints of wire, papier maché, or well-padded straight lateral splints. In cases having much swelling when first seen, this is always the method to be pursued.

If the swelling is very great and shows a tendency to increase, the skin becoming dark and tense, the circulation in the toes bad, and the approach of gangrene evident—all on account of the effusion of blood and serum and not of embolism or thrombosis—free longitudinal incision should be made down to the fracture, blood liberated, bleeding vessels tied, and the lesion treated as a compound fracture (page 518).

For making continuous active traction, two side splints of wood connected below the foot by a crosspiece may be used. Traction may be made by heavy elastic bands, a coiled spring or by weight and pulley (Fig. 463).

Whatever primary treatment is employed, by the end of the second or third veek a permanent light plaster case may be applied. With a plaster case on, the patient may be about on crutches with a lift under the sound foot, care being taken not to make any pressure upon the foot of the injured leg. Six weeks usually shows fairly strong union. By the eighth week the bone should be strong enough to need no splint. Massage may be applied daily. In an oblique fracture, weight may be borne on the leg by the twelfth week, in a transverse fracture by the tenth week. Before permitting the use of the leg, the surgeon should grasp the bones and apply force to test their strength. If any motion at all can be made at the site of fracture, using the limb should be deferred.

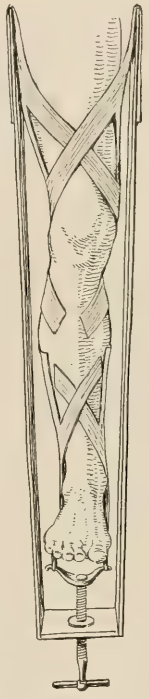


FIG. 463.—FRACTURE OF LEG TREATED BY LONG SIDE SPLINTS AND TRACTION APPLIED WITH A SCREW.

Much skill and patience are required in order to secure good apposition and alinement in the treatment of these fractures. Even under the most favorable conditions and in the most skilled hands the results are not perfect. I have called attention to these difficulties (J. P. Warbasse: "The Treatment of Fractures; Some Practical Points," Jour. of the American Med. Assoc., March 13, 1909). Many subsequent *x*-ray studies have borne out my contentions. While the results from the standpoint of geometric accuracy are often poor, from the standpoint of function they are satisfactory; although it is, perhaps, because of inaccuracies in union that pa-

tients with healed fractures later suffer from the vague symptoms described as "neuralgia," "rheumatism," bone aches, etc. One inaccuracy which should be emphasized is abduction of the lower fragment. It is much better to err toward adduction, as the former displacement is bound to result in weakness of the foot or in flatfoot or eversion.

The treatment of fracture of the tibia alone without fracture of the fibula differs from the treatment of fracture of both bones chiefly in that the displacement is not apt to be so troublesome, and the danger of abduction of the lower fragment is not to be feared.

The **treatment of compound fractures** (page 518) and the methods of applying plaster-of-Paris splints (page 477) have been discussed. If wooden splints or metallic splints are used, they may sometimes be arranged so that they do not require to be removed when the wound is dressed. The posterior metal splint is especially of service if the wound is not posteriorly. The anterior wire suspension splint is of service if the wound is not anteriorly. In the great majority of cases the fenestrated plaster case is the best.

Fractures of the shaft of the fibula, above the lower third, without fracture of the tibia, should be put up in plaster or other splints in such a manner that the ankle and knee are immobilized. Attention should be directed to seeing that there is no adduction or abduction of the knee. The ankle should be immobilized with the foot inverted. Six weeks are required for consolidation, but immobilization of the two joints is necessary for only two or three weeks.

Fractures of the lower end of the tibia and fibula, including separations of the lower epiphysis, are of great variety and amenable to no special treatment. Reduction is accomplished by traction upon the foot and by manipulation. It is most important that the foot be immobilized at a right angle in order to give the most useful position in the event of anchylosis. The best dressing for these injuries is plaster-of-Paris, because it is desirable in many cases to secure pressure upon the malleoli.

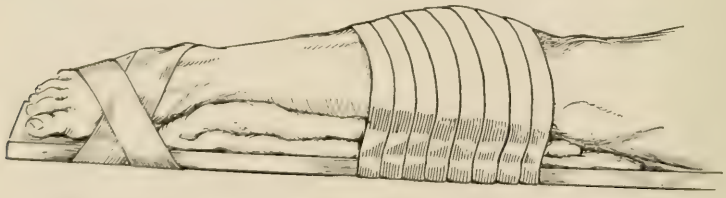


FIG. 464.—COMMON FRACTURE OF LOWER END OF FIBULA.
Adducting splint of Dupuytren. Note thick padding and adduction of foot.

Fractures of the lower end of the fibula ("Pott's fracture"), just above the malleolus, due to eversion and abduction of the foot, and commonly associated with fracture of the tip of the inner malleolus, are among the common fractures of the leg. The characteristic displacement to be overcome is the eversion and abduction of the foot and a tendency to posterior displacement of the astragalus. Reduction is best made under general anesthesia. The foot should be inverted; pressure inward should be made upon the outer malleolus; pressure outward should be made upon the inner malleolus; and the heel should be pressed forward. All of these corrective conditions may be met in the plaster-of-Paris case in skilled hands.

For general use the internal wooden splint (Dupuytren) is to be recommended (Fig. 464). It consists of a stiff board, as wide as the anteroposterior diameter of the leg at the calf, and extending from the middle of the thigh

to 15 cm. (6 inches) below the sole of the foot. Abundant padding of sheets and towels is placed along the inner side of the leg and thigh as far down as the tip of the malleolus. The limb is bandaged to the splint, and the foot is inverted across the end of the padding by a bandage which at the same time draws forward the heel. This drawing forward of the heel should never be neglected. A splint which serves this purpose best has notches at the lower end in which the adducting bandage may engage.

Treatment by means of a posterior and lateral plaster splint (Stimson) is much employed. Plaster bandages, 10 cm. (4 inches) wide, are wet and run back and forth on a table until eight or ten layers are made. These are well

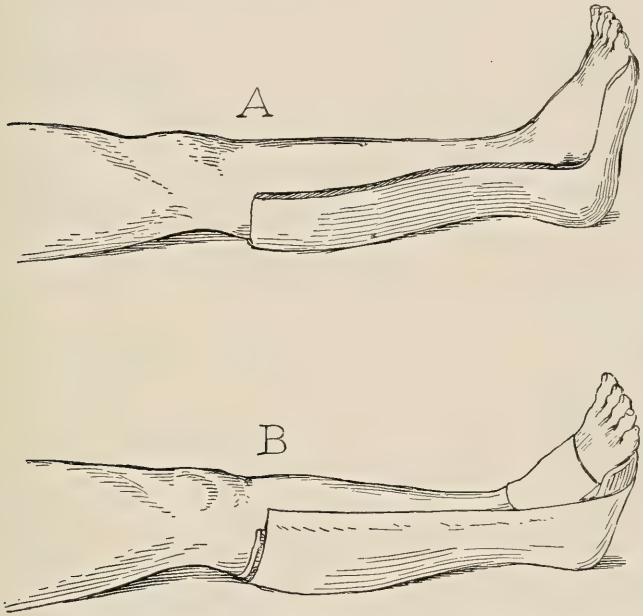


FIG. 465.—POSTERIOR AND EXTERNAL PLASTER SPLINT IN TREATMENT OF THE COMMON FRACTURE OF THE ANKLE.

A, Posterior part of splint applied; *B*, lateral part of splint added. A bandage is applied over all to retain the splints.

rubbed together, and while soft applied so as to extend from the toes, covering the sole and heel, and reaching up the back of the leg nearly to the knee. A similar splint should be made and applied so as to begin just in front of the outer malleolus, pass across the dorsum of the foot, around the sole and up the leg on the inner side to stop short of the knee. These splints are applied after correction has been made. They are moulded to the parts and held by a muslin bandage. After the splint is hard the bandage may be removed and replaced by a few turns just above the ankle and below the knee. While the plaster is hardening the leg should be rotated outward, the heel rested upon a sand-bag, and correction maintained by the hands (Fig. 465).

Stimson called attention to the condition in which there is interposed between the outer malleolus and the tibia a strip of periosteum torn from the tibia, requiring exposure of the fracture and operative correction. In any case if reduction cannot be made by manipulation, correction should be accomplished through open incision.

Old fractures with vicious union are best treated by exposing the site of fracture in the fibula by an anterior incision and dividing the bone. If it is evident that there was a fracture of the inner malleolus, this also should be exposed by an anterior incision and divided. Any exostosis present should be removed. With the bones thus divided correction both laterally and of the posterior displacement is possible.

The **after-treatment** consists in leaving the original splint on for about two weeks; it may then be removed, a light plaster case applied and the patient allowed about with crutches. The foot should always be kept in strong inversion. At the end of four weeks the splint may be removed and daily massage given. Weight should not be borne upon the foot until the end of eight weeks. Unless good correction has been secured there is much danger of a weak foot. If healing takes place with the foot, even slightly abducted, there is always danger of flatfoot. For this reason, overcorrection is better than under-correction. To be on the safe side when the patient begins to walk, the inner side of the sole of the shoe should be made 7 mm. (¼ inch) thicker than the outer side, as is practised in the early treatment of flatfoot.

Fractures of the Tarsus, Metatarsus and Phalanges

These fractures require treatment upon the same principles as the corresponding fractures in the hand. Certain special bones must receive special consideration.

Fractures of the astragalus are best given the support of a plaster-of-Paris case from the toes to the middle of the leg. This may be bisected and removed for inspection. The foot should be at a right angle to the leg, care being taken to see to it that there is no abduction, or anteroposterior displacement. Any loose fragment which can not be manipulated back into place should be exposed by incision and replaced; or, if infected and completely detached from its vital connections, removed. Massage should be begun early.

In some compound fractures, fractures with infection, and in badly comminuted fractures, the whole astragalus may be removed, and a better functional result often secured than by more conservative treatment.

Fractures of the os calcis, if complete, are characterized by relaxation of the plantar bands, which hold the bones arched, and by a tilting upward of the back of the os calcis. The first essential in treatment is to relax the tendo Achillis. This may be done by plantar flexion of the foot, by flexion of the knee, or by tenotomy of the tendo Achillis—one or all. Unless this is done, a flattened foot will result. The best immobilization is secured by a plaster-of-Paris dressing, applied with especial firmness above the heel, to hold down the posterior fragment. In place of this, traction upon the heel, applied through adhesive plaster, may be combined with lateral wooden splints, and pads just below the malleoli, to make lateral pressure. These methods not succeeding, the fragment may be sutured or pegged in place. After two or three weeks, union is sufficiently firm to permit the use of massage. Weight should not be borne upon the foot for at least three months. Crushing and comminuted fractures require the above-described treatment. Fractures of the sustentaculum tali should be put up with the foot inverted. Fractures of the os calcis, complicated with fracture of the astragalus, demand the meeting of the conditions peculiar to each case; in general, a pad below each malleolus to give lateral pressure is of the most service.

Fractures of the metatarsal bones require a simple supporting dressing, preferably of plaster-of-Paris, extending from the toes to above the ankle.

Any slight tendency to displacement is met by a well-powdered pad of gauze. The most important feature of the treatment is that no weight should be borne upon the foot for at least two months after the injury. Massage may be instituted by the end of the second or third week.

Fractures of the phalanges of the foot are treated by a plantar splint of wood, extending from the heel to the end of the toe. Under the toe should be placed a small roll of gauze, over which the toe is flexed in its normal position. Sometimes more comfort is secured for the patient by enveloping the toe in a gauze bandage and then bandaging it fast between the two adjacent toes, not using any other splint. Compound fractures require no more splint than is furnished by the dressing.

DISLOCATIONS

In treating dislocations the surgeon should have a clear mental picture of the anatomic conditions with which he is dealing. Besides the normal anatomy of the part, he should think of the distorted relations, the torn capsular ligament, and the structures stretched and compressed by the distortion. The longer the parts are left in their abnormal relations the more difficult does reduction become. The parts become infiltrated with serum and blood, lacerations heal in distorted relations, the damages and changes incident to pressure become more permanent, synovial surfaces which are not in contact with synovial surfaces become adherent to other structures, until reduction becomes impossible.

Reduction of dislocations should be done as soon as possible after the accident. Rarely is there justification in waiting until swelling or traumatic reaction have subsided. The longest time which may elapse before reduction can be done without operation varies greatly. Usually after four weeks it is difficult or impossible. In some cases it has been done after two months. This is exceptional. The difficulties increase with each succeeding day.

A few dislocations require a general anesthetic—the hip usually; sometimes the shoulder, knee and elbow. Ether is the anesthetic of preference. Chloroform is the most dangerous, the largest percentage of fatalities from this drug being observed in the treatment of dislocations. The chief *obstacles* to reduction are not the contractions of muscles but the mechanical obstacles offered by bones and ligaments; and in the case of ball-and-socket joints the capsular ligament is the main hindrance. Interposed muscle, fascia, or tendons, or torn-off pieces of bone or cartilage also may prevent reduction. If the head of the bone has escaped through a rent in the capsule reduction may not be difficult so long as the head lies at the rent; but if secondary displacement has taken place and the head has moved away from the opening until it has between it and its socket a barrier of untorn capsule, reduction becomes more difficult. If now the rent in the capsule closes like a buttonhole, reduction without operation may be impossible.

Although history furnishes isolated examples of surgeons reducing dislocations by causing the bone to retrace the course which it followed out of the joint, still until the early part of the nineteenth century dislocations were almost universally reduced by the application of enormous force, applied in the direction of a line between the two dislocated surfaces. This old method resulted often in much damage to the parts and further tearing of ligaments. Nathan Smith inaugurated the modern treatment of dislocations. He practised and taught reduction by manipulation.

Usually both the surgeon and patient are aware when the dislocation is reduced. The bone goes back into place with a snap, the contour of the joint is restored to normal, the sensations of pain and tension are relieved, and the joint is capable of free movement. If a recent dislocation cannot be reduced operative treatment is called for. In old or feeble persons in whom an irreducible dislocation is not causing pain or circulatory disturbance, the surgeon is justified in allowing the bone to remain unreduced and to form a new joint rather than subject the patient to the hazard of open operation.

The **after-treatment** of dislocations consists in the application of a bandage or splint to keep the joint quiet for two weeks, after which massage and passive motion may be employed. In the large joints the parts should be kept at rest for four weeks to insure firm union of the torn ligaments.

Doubtful reductions are those in which, while some of the symptoms of dislocation have been overcome, the surgeon feels that everything is not right, and that the parts have not been restored absolutely to normal apposition. This may be due to a fold of capsular ligament falling between the bones, or the presence of muscle, displaced cartilage or fragment of bone. A fracture complicating a dislocation also belongs to this category, and may cause the persistence of dislocation symptoms after the dislocation is reduced, or it may cause a simulation of reduction when reduction has not been effected.

Operative treatment is called for in recent dislocations when manipulation or manipulation combined with reasonable force have failed to achieve a complete reduction. Usually one of the incisions used in arthrotomy is employed. The joint is exposed, and with the aid of the eye reduction is accomplished. Often it becomes necessary to divide ligaments and sometimes tendons which are discovered to be the cause of obstruction; or the head of a bone may require to be removed. After effecting reduction the cut and torn ligaments are sutured.

Complications, to be treated and guarded against in the treatment of dislocations, are of the greatest importance, and are so many that these njuries belong among the serious surgical lesions because of them.

Fractures complicating dislocations may involve one or both of the bones, and by causing a loss of leverage may make reduction by manipulation or even by force impossible. When such is the case operative treatment becomes necessary. The joint should be exposed, reduction accomplished, rents of the capsule sutured if accessible, and the fracture united by suture or some other of the methods already described.

Injuries of blood-vessels are among the serious and not uncommon complications both of dislocation and efforts at reduction. Every care should be taken to avoid these accidents. The longer reduction is delayed the greater is the danger. In many situations, the vessels are so close to the joint that the dislocated bone tears them; or they become involved in the traumatic exudate and are attached so closely to the dislocated bone that the manipulations of reduction cause them to be torn. These injuries may be only partial tears giving rise to embolism, thrombosis, or aneurism. Complete tears of the artery or vein cause hemorrhage which is often fatal. These accidents occur most frequently in connection with the shoulder, but they do occur at the elbow, knee and other joints. They are best avoided by early reduction, with as little force as possible. When thrombosis has occurred, reduction should still be accomplished. The future care of the limb becomes that of threatened gangrene. When a vessel, such as the axillary artery, is ruptured, local pressure should be applied, and reduction accomplished; pressure upon the trunk should then be made above while the seat of the injury is exposed and dealt with according to the rules laid down for the treatment of wounds of blood-vessels.

Injuries of nerves occur not uncommonly, and are due to contusion, laceration, and compression by bone or exudate. Reduction should be effected, and then examination of the distribution of the nerve made. If the nerve has been severed it should be exposed and sutured. If the paralysis is due to the contusion or exudate, massage and time may be depended upon to accomplish a cure.

Rupture of muscles may be caused by efforts at reduction. These injuries should not be confused with those which were caused by the same force which produced the dislocation. They rarely require any other treatment than rest.

Infection of the lacerated tissues, of endogenous origin, may require attention after a few days. Such infection demands free exposure and drainage. Gangrene may result, and amputation become necessary.

Edema may persist as a result of compression or thrombosis of the vein. It subsides under massage, bandaging and elevation. If due to unreduced dislocation, it adds another reason in favor of operative reduction.

Fatal results occur both as the result of dislocation and as the result of attempts at reduction. Persons with some systemic weakness, disease of the heart, or glandular derangement, are especially susceptible to the depressing effects of dislocations. The damage to the nerve trunks and great vessels which lie close to the large joints produces a peculiarly high degree of shock. When interstitial hemorrhage is added to the nerve injury it is often fatal although the amount of blood escaping from the vessels is not large. For these reasons dislocations of the large joints must be treated with every effort to conserve the strength of the patient and to avoid depressing influences.

Compound dislocations should receive the most scrupulous aseptic care. Fortunately they are usually of the smaller joints. All gross signs of dirt should be washed off with antiseptic solution or sterile water. The surrounding skin should be shaved and cleansed as for an operation. After reducing the dislocation, provision for drainage should be made, if necessary. The treatment is the same as for compound fractures (page 518).

Old unreduced dislocations are dangerous lesions in which to attempt reduction, especially in persons with sclerotic vessels. A large number of fatal results have followed attempted reductions of old shoulder dislocations. The time at which a dislocation becomes too old for reduction by manipulation varies with every case. Usually after two months it may be designated as old. Many cases cannot be reduced without tearing blood-vessels a week after the injury; others may be reduced after the lapse of several months. Judgment is required.

In doubtful cases, all readiness should be made to meet emergencies. In many cases some treatment is necessary to relieve pain. If the danger of damage of large vessels is great manipulation had best not be attempted; but instead the head of the dislocated bone should be exposed by an arthrotomy incision and carefully dissected away from the vessels. If such an operation cannot be done, it will often become advisable to do an osteotomy, severing the dislocated head from the shaft, and then dissecting it away. If there is no pain, and the limb is fairly useful, in an old person, in the large joints, old dislocations are best left unreduced. If ankylosis is present, osteotomy may be employed to improve the position or produce a false joint.

Habitual or recurrent dislocations are treated by correcting the condition responsible for the lesion. If the cause is elongation or relaxation of the capsular or other ligaments, the best results are secured by exposing the ligament, shortening it either by making a fold or by dividing it and overlapping the edges of the wound, and holding it with interrupted sutures.

Injections with a hypodermic needle of irritating substances may be made outside of the joint to affect the capsule; or if some joint adhesions are desired the injection may be made into the joint. For this purpose alcohol combined with a little morphin and cocaine may be used. But a few drops are required to set up the desired irritation. The fluid should be deposited

in many places about the joint. Repeated injections may be made. For injections into the joint, tincture of iodin is most effective. These methods are of special service in dislocations of the clavicle and humerus.

Dislocations habitually recurring because of a defect in the wall of a socket are treated by repairing the defect. The tearing loose of muscles at their insertion is sometimes found. For this reason in operating for this condition the surgeon should have in mind the anatomy of the part and look for this lesion. The muscular insertion may be sutured back in place and its healing facilitated by putting up the limb in such a position as to relax it. The dislocations which habitually occur in connection with paralysis of the nerves supplying the part are not to be treated as are the other dislocations. Here the paralysis is the main thing. The limb is of no service unless the paralysis is overcome. If the atrophy has caused so much relaxation of the ligaments and muscles that the bone drops out of its socket continually some improvement of the distressing condition may be secured by putting it back and producing ankylosis (see Arthrodesis). An operation for shortening the capsular ligament may be done the same as in habitual dlslocations.

Spontaneous dislocations are those which occur as the result of diseases of the joint, causing distention by fluid, destruction of the elements of the joint, deformity, or paralysis. In all of these cases the causative disease is the important thing to be treated. When that has received the necessary attentions, reduction of the dislocation is called for. This should be attempted by the ordinary methods which are applied to traumatic dislocations. Traction is often of special service. To overcome spastic muscles continuous traction is often necessary. These methods failing, open operation becomes necessary.

Distortion, associated with ankylosis, following dislocations, may be corrected by osteotomy below the head of the bone and fixation and healing in the desired position.

Congenital Dislocations.—Congenital dislocation of the hip may be taken as the example of this class of lesions: the condition is very rare in other joints. There are three methods of treatment: (1) traction, (2) manipulation and fixation, and (3) bloody reposition. The first of these is of service only in very young children in which there is much mobility of the head, and is rarely applicable.

Reduction by manipulation has been much employed during recent years. A satisfactory result has been secured in about half of the cases, although the percentage of cases in which a true anatomical reduction of the dislocation has been obtained is much less than this. Some surgeons report improvement in over 90 per cent. of cases thus treated, with ideal results in 60 per cent. of unilateral cases and in 40 per cent. of double dislocations. One surgeon has reported 700 cases with 85 per cent. of perfect functional results in unilateral cases, and 30 per cent. in bilateral cases, Hoffa in 600 cases had satisfactory anatomic and functional results in 70 per cent. of unilateral cases between two and eight years of age, and in 20 per cent. of double dislocations treated between the ages of two and six years. In patients older than these the percentage of successes becomes rapidly less as the age increases.

The *age* at which treatment may be successful is most important. It may be said that no child is too young for manual correction to be begun. Bilateral dislocation can usually not be successfully corrected in children of more than six years of age, and unilateral dislocation in children over eight or ten years of age. Infancy is the best period for treatment as soon as the child begins to develop regularity of habit in its excretory functions. Lorenz

gave the age limit as nine to ten in unilateral and seven to eight in bilateral cases. He preferred to treat children at three years of age. No case in a civilized community should go undiagnosed and untreated beyond the age of three years.

The *technic* of the operation now employed represents the combined advantages of many operations. The patient is laid recumbent upon a table in a completely anesthetized state. The leg is then pulled down strongly while an assistant makes counter extension at the groin and tuber ischii. The thigh is then rotated outward and inward in the flexed position, with the knee both straight and flexed. The thigh is then forcibly abducted, both with the knee straight and with the knee and thigh flexed. Abduction is continued with the knee and thigh flexed until the outer side of the thigh lies upon the table, the thigh being at a right angle to the trunk (Fig 466).

FIG. 466.—CONGENITAL DISLOCATION OF HIP.
By manipulation and stretching the thigh has been brought to a position of abduction at a right angle.

The same degree of abduction should then be secured with the knee extended. In order to secure this abduction it is necessary to rupture or stretch the adductor muscles. The yielding of these muscles may be facilitated by deeply kneading or massaging them when they are made tense. The thigh is then flexed, with the knee also flexed, until the knee can be brought into contact with the chest. The child is then brought to the lower end of the table, and the thigh hyperextended with the knee flexed and extended. The object of all of these manipulations is to stretch, tear and relax the soft structures about the joint which are holding the bones in dislocation. The movements will not succeed unless made forcibly and carried to the point of overcoming the resistance. At least two pairs of hands are required. The pelvis must be held, the leg moved and the resisting soft tissues massaged. The amount of force varies with the age of the child. Force should not be too great nor suddenly applied. Unless care is taken the femur may be fractured, and that means discontinuance of the manipulations.

Having sufficiently relaxed the parts, the next step is the reduction of the dislocation, which is accomplished in much the same manner as in an ordinary dislocation. The child lies supine; the hip is flexed and abducted; the surgeon firmly grasps the limb with one hand, continues the abduction of the flexed thigh, and presses forward against the back of the trochanter. A rocking, rotating motion is made, and the head of the femur rides over the posterior part of the rim of the acetabulum into its socket with a click. This is preferable to bringing the head over the lower border of the acetabulum. When the head is once in place, it should not be allowed to leave the socket. The leg should then be brought down carefully in the straight position. If the head slips out, the stretching of the parts should be repeated and carried still further. Very resistant cases require subcutaneous division of the adductor tendons at their pelvic origin, division of the iliotibial fascia, or of the fascia lata below the anterior-superior spine of the ilium.

The hamstring muscles should not be overstretched by the operation. Reduction can be accomplished usually without stretching these muscles. They serve an important function in holding the head in the socket against the Y-ligament. After the reduction the hamstring tendons should be found tense. The tenseness of these tendons is a valuable sign during the course of confinement of the limb as it is an indication that the head is in the socket.

This operation is not free from *dangers*. Among the accidents reported are fractures of the shaft and neck of the femur, fracture of the pelvis, both temporary and permanent paralysis of the limb, rupture of the femoral vessels, necrosis of the soft tissues, extensive extravasation of blood and serum, abscess, and death from shock.

Hibbs, Bartlett and Bradford have devised apparatus for effecting this reduction. In younger children and in simple cases the purely manual method is best. Such apparatus is used in older children and in certain difficult cases. In the hands of their inventors these mechanisms have given a larger proportion of successes than has the simple manual reposition.

The after-treatment now most employed consists in placing the child upon a pelvic rest and applying a plaster-of-Paris case to the thigh and pelvis, the hip being flexed and abducted to such a degree that the patella is at or just below the level of the pubic arch when the child lies on its back. The thigh should be abducted to make a right angle with the long axis of the body, flexed to a right angle and rotated inward. The plaster is applied over a layer of tricot or other cloth, snugly embracing the pelvis including the leg and foot of the corrected side, and the upper part of the thigh of the other side in order to secure fixation. Abundant room should be left for urinary and fecal discharges. The edges should be painted with water-glass or shellac and kept protected from soiling.

After the traumatic reaction of the reduction has subsided, the child may have a lift placed under the shoe of the affected foot, and be permitted to walk about (Fig. 467). If old enough the child may use crutches. The use of the limb in bearing the weight of the body helps to deepen the acetabulum by the pressure of the head. At the end of two weeks the splint may be cut away from the sound thigh. After two months the plaster case below the knee and, at the end of three months, the rest of the splint are taken off, an *x*-ray picture made, and the hip again put up in plaster, but with less abduction and flexion. The child is allowed to go about for two or three months more, when the case is again removed, examinations made, and another case applied, the limb being brought down still more toward the straight position. The immobilization of the hip is continued. In some cases six months suffice, in others, a longer time must be given to fixation—nine

months or a year. Passive motion and massage should be given for some time before the child is allowed to go without the splint. Some surgeons leave the splint on for a year with only one renewal during that time.

FIG. 467.—PLASTER-OF-PARIS FIXATION AFTER REDUCTION OF CONGENITAL DISLOCATION OF HIP.

Reduction by open operation has some advantages of the manipulative treatment. Rubber gloves should be worn and rigid asepsis practised. An incision is carried from the anterior-superior iliac spine to the base of the great trochanter. The space between the rectus femoris and the anterior border of the tensor vaginæ femoris is entered. The rectus is retracted inward and the gluteus medius is retracted outward. The capsule is then split widely enough to expose the head and neck of the femur. It is also

divided at its outer attachment around the whole base of the neck. This is accomplished by flexing the thigh to a right angle. The ligamentum teres is cut, and the head dislocated into the wound. The acetabulum is exposed and cleared of capsule. If it is still shallow, it should be deepened by the curet. It is especially important that the upper border of the acetabulum should be made to present an adequate barrier against riding up of the head. This upper border should not present an inclined plane upon which the head can slide up and out of the socket, but the cavity should be excavated so that the upper rim is made overhanging. This is one of the most important features of the operation. The head is then returned to the acetabulum, and the capsule sutured. Drainage may or may not be employed, depending upon the asepticity of the operation. The joint is put up in strong abduction in a plaster-of-Paris case reaching from the axillæ to the toes. Dressings are done through a fenestrum. At the end of two weeks the splint is removed, the thigh brought down toward the straight position, and a plaster case, involving the pelvis and thigh, applied. This is left on for a month while the child goes about with a lift under the sole. Another splint is applied after the thigh has been straightened still further; and by the end of four months the splint may be dispensed with. Passive motion and massage are applied during the last month.

The *choice of methods* should depend upon the degree of spasticity of the joint and the perfection of asepsis which the surgeon can command. Operative treatment, except in the hands of the best-equipped surgeons, is still dangerous and uncertain. With good asepsis, there is less danger in the bloody operation than in the bloodless procedure. At present, experience points to the advantage of the manipulative treatment in children between two and five years of age when reduction is most easy. It is successful in most cases up to the tenth year, but the probability of success diminishes with the increasing years. The bloody operation is now applied in cases in which recurrence of dislocation has followed the manipulative treatment, in children over twelve years of age, and in cases in which examination shows insurmountable difficulties in the way of bloodless reduction. It was my privilege to have worked with Lorenz as a student in Vienna in 1892 when he was experimenting with the bloody operation, and I became impressed with the belief that this is the more surgical treatment of the two, although at that time his results were bad. The chief drawback then and now has been infection. Death from sepsis has occurred in some cases. Reduction but with ankylosis has been a common result. As Julius Wolf has aptly said, "Before the operation the children walk like ducks, and after the operation they walk like lame ducks." Still with modern technic the danger of infection is being steadily diminished, and with this improvement a larger percentage of cases should have applied to them the cutting operation.

(For a further discussion of the treatment of congenital and paralytic dislocations of the hip, see Bone Grafting, page 783.)

Congenital dislocation of the knee should not be confused with congenital *genu recurvatum*. The treatment of the latter condition consists in the application of a splint to hold the knee slightly flexed and later to be worn in such a way as to prevent hyperextension. If a true dislocation is present, usually with the head of the tibia displaced forward, reduction is accomplished by manipulation. It may become necessary to stretch all of the parts by hyperextension, flexion, and lateral motions after the method practised in the hip. If stretching does not overcome the contraction of the extensor muscles, it becomes necessary to lengthen the muscle by myotomy or by lengthening the patellar tendon (see Muscles and Tendons, page 799).

Deepening of the articular surfaces of the tibia and shortening of the crucial ligaments have been done.

Congenital dislocation of the ankle occurs usually as a result of defective development either of the tibia or fibula. When as a result of unequal growth of one or the other of these bones the foot is thrown into abduction or adduction, correction is accomplished by the use of a shoe, holding the foot in natural position. By this means, as the child walks, growth of the side, receiving the minimum pressure, is encouraged to be more active than growth of the other side of the ankle, and the hope may be entertained that an equalization of the two sides will be accomplished. If this fails, or if from the beginning the dislocation is too extreme for this treatment, supramalleolar osteotomy is called for, and if necessary the excision of a segment of bone or the plastic elongation of the other bone.

Congenital dislocations of other joints are so rare as to be curiosities. In the *shoulder* the treatment is the same as that of ordinary dislocation, excepting that fixation may be required by tightening the capsule, as is done for habitual dislocation. In the *patella*, the treatment is the same as for habitual dislocation. Congenital dislocations of the *elbow* are treated the same as in the knee. Dislocation of the head of the *radius* is apt to be complicated by elongation of the bone, making reposition impossible: this calls for excision of the head. At the *wrist*, the congenital dislocations are similar to those at the ankle, and require the same treatment. Club-hand is discussed elsewhere.

DISLOCATIONS OF THE LOWER JAW

Forward dislocation of the condyles of the lower jaw is usually bilateral, although it may be unilateral. The capsular ligament is not necessarily torn; commonly it is stretched. In cases seen early, reduction is easy. Indeed, reduction sometimes takes place spontaneously. The condyles have ridden forward over the eminentia articularis of the temporal bone, and it is only necessary to cause them to move downward and then backward to effect reduction. This is accomplished by placing the patient in a chair with his head resting against a solid back. The surgeon then has his thumbs enveloped in a bandage to protect them from being bitten. The two thumbs are placed against the back molar teeth on either side while with the rest of the hands and fingers the body of the jaw is grasped. Strong downward and backward pressure is made with the thumbs and at the same time the ring and little fingers lift up the front of the jaw (Fig. 468). As the condyles slip back the thumb should be withdrawn quickly lest they be bitten. The jaw should be held closed by a bandage and the patient fed on fluids for two weeks. The mouth may be kept sweet by washing it with milk of magnesia alternating with boric acid solution, and cleaning the outer surfaces of the teeth with a brush. The mouth should not be opened widely for six weeks after the injury.

If the coronoid process is caught under the malar bone, it may be disengaged by opening the mouth a little wider before attempting reduction. The sooner the lesion is treated the easier will it be reduced; but reduction is not impossible in a dislocation of three months' standing. In old dislocations adhesions should be loosened by working the jaw up and down under general anesthesia before attempting reduction. In place of the thumbs, pieces of wood, 7 to 13 mm. (¼ to ½ inch) thick, acting as fulcra, may be placed between the back molar teeth, and upward pressure made at the symphysis menti. Unilateral dislocation is treated by the same principles.

Old irreducible dislocations may be treated by operative exposure of the joints and division of the obstructing tissues. Or subcondyloid osteotomy may be done: this permits the ramus to ride back, and gives a very useful jaw. In a case of irreducible dislocation Stimson exposed the joint and found that the meniscus had been torn from the condyle, and was lodged in the glenoid cavity in such a way that the condyle could not be replaced. After removing the meniscus reduction was easy. (See Operations on Bones and Joints, page 688.)

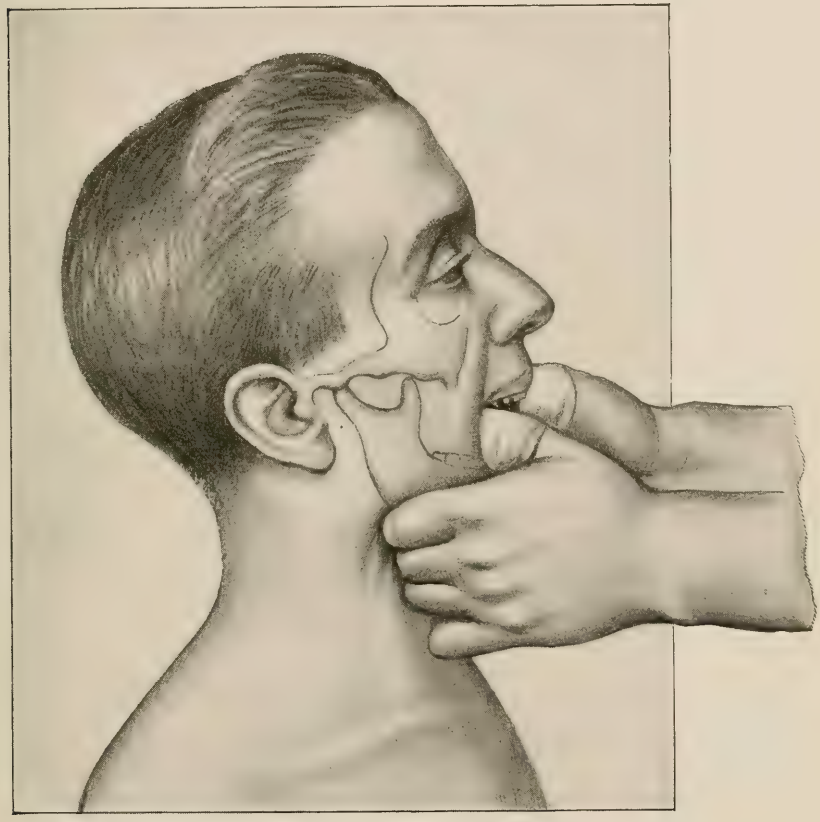


FIG. 468.—METHOD OF REDUCING DISLOCATION OF LOWER JAW.

Backward dislocation is treated by pressing the jaw forward by means of the fingers, grasping the body and rami on either side.

Outward dislocation is treated by making pressure upon the condyle in a downward and inward direction while the body of the jaw is pressed downward and toward the middle line.

Upward dislocation through the fractured glenoid cavity has been reported. The indications in such a case are to draw down the dislocated side by pressure on the back molar teeth with the thumb or some stronger leverage. In the event of not being able to accomplish this the joint should be exposed, the neck divided, the head of the bone grasped and removed, fragments of temporal bone picked out, and the wound drained for a few days.

DISLOCATIONS OF THE VERTEBRÆ

Dislocations of vertebræ concern the two articular facets by which each vertebra articulates with its neighbor. Dislocations are not of a single vertebra but are *between* two vertebræ. They are serious injuries because of the damage to the cord and spinal nerves with which they are prone to be complicated. Treatment cannot be satisfactorily carried out unless an accurate diagnosis is made. To accomplish this, must be brought to bear the best diagnostic abilities of the surgeon. Much light can be thrown upon the case by examination of the peripheral nerves, and collating the results of the examination with the anatomy of the nerves and cord. Often the palpation of the bones gives little light upon the case. Dislocations are very commonly associated with fractures of vertebræ; and both lesions are often complicated by laceration, or by compression of cord or nerves by either bone or blood clot. Differentiations between laceration, compression, hemorrhage into the cord, subdural hemorrhage, and dislocation are often called for. Careful study of the case is well worth while. The *x*-ray can add help of great value. There are several degrees of dislocation requiring treatment. Dislocation may be unilateral or bilateral. Both facets may be dislocated forward or backward, or one forward and the other backward. The dislocation may be complete or incomplete. But whichever it is, much can be done for these cases; the surgeon should beware of treating them as fractures by immobilization when reduction of dislocation is called for.

Complete dislocations are those in which the two articulating facets of one or both sides are entirely separated from one another. Reduction is easier the sooner it is attempted. It has been accomplished successfully after the lapse of several days. It is best done under general anesthesia, although anesthesia is not necessary. The surgeon should understand just what he wishes to do; and before attempting reduction he will do wisely to examine the bones of the skeleton placed in the position in which he believes them to be in his patient.

Treatment is most commonly required in the neck. If the dislocation is unilateral, the patient should be placed on his back on the table, an assistant should make counter extension by holding the shoulders, traction should be made upon the head by another assistant grasping at the lower jaw and occiput, while the surgeon presses the deviated spinous processes toward the middle line, and at the same time directs that lateral flexion be combined with the traction upon the head. Lateral flexion of the spine should be made with its convexity toward the dislocated side. If this has not been determined by the local examination, it may be determined by the peripheral nerve disturbances. Paralysis or tingling of the nerves of the hand or foot may furnish the clue as to which side is involved. The illustration of a unilateral dislocation between the fifth and sixth cervical vertebræ (Fig. 469) shows the obstacle to be overcome. The case here shown is one in which I failed to make a diagnosis until the possibility of reduction had passed; although the patient is now employed as a motorman, running a trolley car through the streets of New York.

The common complete dislocations are dislocations *forward* of the *upper* vertebra. In the cervical region, dislocation of the upper member backward may be a slight subluxation, or the transverse process may ride back against the upper edge of the articular process below it, or it may pass completely over it and engage against the articular facet. These posterior displacements of the upper member may be of any degree; and they are naturally

more easy of reduction than anterior displacements. They give less lateral deviation of the spinous process but they may cause even more disturbance of peripheral nerves. Whether the dislocation is anterior or posterior, reduction requires lateral flexion of the spine with the convexity toward the lesion, and pressure of the laterally separated spinous processes toward the mesial plane. If the upper member is dislocated forward, its spinous process will be rotated toward the dislocated side, carried forward and upward, and leaving the spinous process of the lower member more prominent and apparently deviated in the other direction. If the upper member is dislocated backward, its spinous process may not be perceptibly out of line, and only a slight effort is required to effect reduction.

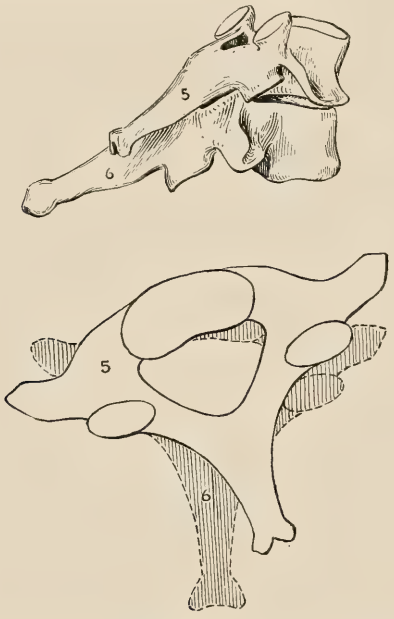


FIG. 469.—UNILATERAL FORWARD DISLOCATION OF FIFTH CERVICAL VERTEBRA.

Showing that the inferior articular process of the fifth must be made to pass upward and backward over the superior articular process of the sixth in order that the fifth may be reduced into its normal position behind the sixth. Only strong lateral flexion, with its convexity toward the dislocation, and backward rotation of the right side of the upper vertebra, can accomplish this. (*After Cotton.*)

Bilateral dislocations are most serious if both sides are displaced in the same direction. Here bony compression of the cord is inevitable, and reduction is imperative. If one side is displaced forward and the other backward the danger to the cord is less. Reduction in either case must be accomplished by traction and an attempt to reproduce the position in which the lesion occurred. If strong flexion caused the dislocation, the traction should be combined with flexion while efforts to press the bones into place are made. The condition is a serious one, and attempt at reduction is serious, and the friends of the patient should be so advised. Efforts at reduction of dislocations in the neck may cause instant death. It should be the patient's privilege, through himself or responsible friends, to elect not to accept the hazard of attempts at reduction. This he may wisely do if the nerve disturbance is not great, because after the traumatic exudate has been absorbed the paralysis improves.

When reduction of a complete dislocation is accomplished, the bones usually go together with a snap. The parts should be immobilized in plaster-of-Paris for a period of two to four weeks. If fracture also is present the immobilization should be longer. In the neck a cuirasse of plaster, covering the shoulders and upper thorax, the neck and head, should be put on (Fig. 189). In the other parts of the spine a plaster jacket should be used.

Irreducible dislocations require much judgment as to their treatment. As the symptoms are partly due to traumatic swelling, exudation and hemorrhage, the surgeon cannot always know how much permanent damage will remain. He may usually be sure that there will be more or less improvement. After several efforts at reduction have failed, more force being used with each succeeding attempt, if the dislocation is bilateral and the cord is compressed, operation is indicated. If the lesion is unilateral, operation is not necessary unless the symptoms indicate that the cord is compressed by bone. The higher in the neck the lesion, the greater the danger. It is not customary to operate if the lesion is above the fourth cervical, but there is no contraindication to attempting operative relief in any part of the spine. The proportion of cases in which operative treatment is being applied is steadily increasing. If operative treatment does not seem indicated, if the nerve disturbance is but slight, the part should be immobilized just as after reduction.

Operative treatment is applicable to most irreducible displacements. A liberal median incision is made behind the spinous processes. The muscles are dissected away from the processes and laminæ, and the dislocated articular processes are exposed. With the aid of sight it may be possible to reduce the dislocation. As we look at the lesion (Fig. 267), it is apparent that if the posterior articular process cannot be made to ride under the one above, the solution of the problem is to shorten it or cut it off. This is easily done with bone forceps, and the obstacle to reduction is removed. If there is a bilateral anterior dislocation of the upper member, the two sides will require to be exposed, the capsules of the joints divided, the offending upper processes of the lower bone cut off, and reduction accomplished. In dividing the articular processes care should be taken not to injure the nerve emerging in front of it, nor the vertebral artery passing up in front of the nerve. The danger is not great because both of these structures are carried abnormally forward by the dislocation.

In posterior dislocation of the upper bone reduction is most easy; but if it has not been accomplished, operative exposure of the spinous processes, laminæ and articular processes is indicated. This being done, it may be possible, to grasp the spinous process of the forward-dislocated vertebra with strong forceps, and, while making counter-pressure upon the vertebra above and traction on the head, pull it back into place. Failing in this, pressure upon the cord may be relieved by cutting away the laminæ of the lower vertebra.

Dislocations between the occiput and **atlas** and **between the atlas** and **axis,** if the patient survive, should have the benefit of corrective efforts, made by applying traction to the head while careful pressure is made to overcome displacement.

Dislocations of the lower six cervical vertebræ are the common dislocations, and are taken as the types for treatment described above.

Dislocations of dorsal vertebræ are treated by extension and corrective pressure.

Dislocations of lumbar vertebræ are corrected by traction, ventral flexion, and pressure upon the prominent vertebra.

Subluxations of vertebræ occur in all parts of the spine and in all degrees. When the dislocation is so slight as not to effect the spinal cord, it will still produce disturbances in the spinal nerves, passing off through the spinal foramina. The dominant teaching has been that dislocations were gross lesions, causing pressure upon the cord, easily palpable, and with a high mortality. Blasius, (1869) showed that slight dislocations occurred, which presented but slight symptoms. Then nearly half a century elapsed, during which time a pseudoscience sprang up as a result of the scientific neglect of these common subluxations. We are indebted to H. P. deForest, of New York, for placing this whole subject upon a scientific basis, and showing that a large category of peripheral nerve disturbances are due to such subluxations and are relieved by treatment upon this basis. He demonstrated the finer displacements which had escaped the notice of Blasius, and applied successful treatment. As a result of the work of deForest many cases of "neuralgia," "rheumatism," "lame back," "crick in the back," "stiff neck," vague abdominal symptoms, and girdle pains may be cured by looking for these slight dislocations and correcting them.

The technic of treatment is simple. Little or no force is required. Spontaneous reduction often takes place. Slight traction upon the spine is made either by the hands or with the suspension apparatus, the patient sitting upright in a chair. While traction is made, corrective manipulation is applied to the displaced vertebra. When the bone slips into place, which it often does with a snap, the patient feels a sense of relief from the pressure upon the spinal nerve trunk. In some cases no displacement is palpable, but empiric pressure and manipulation cause relief of the symptoms. In such cases deForest employed vibratory massage in connection with traction.

DISLOCATIONS OF THE RIBS AND COSTAL CARTILAGES

Dislocations of ribs from vertebræ are to be differentiated from fracture of ribs and reduced by pressure and appropriate manipulation. In the event of failure to reduce, the rib should be exposed near its vertebral end and lifted into place.

Dislocations of costal cartilages from the sternum, from the ribs, or **from one another** are to be treated the same as fractures of the ribs. Displacement is corrected by pressure, and immobilization secured by a broad adhesive strip. Tendency to recurrence is overcome by means of a firm pad beneath the adhesive bandage.

DISLOCATIONS OF THE CLAVICLE

Forward dislocation of the sternal end of the clavicle is reduced by drawing the shoulder outward and the shoulder and clavicle backward, by making backward pressure on the dislocated bone. Reduction is usually easy. The chief difficulty is to maintain the correction. Cases with little tendency to recurrence may be treated by a simple bandage, holding a pad against the clavicle and fixing the upper arm to the side of the chest, so that the shoulder cannot be raised.

Most cases require something more than this for permanent fixation. It is best that the shoulders be drawn forward in the "round-shouldered" position and fixed there by means of a figure-of-eight plaster-of-Paris bandage around the shoulders and across the front of the chest (see Bandages, Vol. III), a pad of gauze being interposed to make pressure on the inner end of the clavicle. Stimson cites Nélaton as using an ordinary hernia truss, one pad

pressing on the clavicle, the other between the shoulder blades, and the spring carried under the axilla. When pressure is maintained by pads, the skin should be inspected frequently, rubbed with alcohol, dried and powdered, and if possible the pads shifted at intervals. Digital pressure should keep the bone in place while the skin is receiving attention. Rest in bed with a sandbag lying on the clavicle has been effective. It is necessary that these measures should be continued for two weeks, after which a simple bandage with fixation of the upper arm is necessary for two or three weeks longer.

Recurrent dislocation is not uncommon, and requires continuation of fixation or operative treatment. Of the latter, injections of alcohol, or operative tightening of the capsular ligament are effective.

Backward dislocation of the sternal end of the clavicle is reduced by drawing the two shoulders backward, having the patient take a full breath, while the surgeon presses the shoulder outward or grasps the clavicle and draws it forward. A figure-of-eight bandage around the shoulder and across the back should draw the shoulders backward. The upper arm should also be bandaged to the side to prevent raising the shoulder. The dressing should be worn for at least a month.

Upward dislocation of the sternal end of the clavicle is reduced by drawing the shoulder outward and downward while pressure is made in the same direction upon the sternal end of the dislocated bone. A simple immobilizing bandage of the shoulder and arm may be applied (see Bandages). If there is much tendency to recurrence the following dressing may be used: A strip of adhesive plaster, 8 cm. (3 inches) wide, is carried up the back, over the inner end of the clavicle, and down in front of the chest. Behind, it is made adherent to the skin; over the clavicle, it is made adherent to a firm pad; from here down, the adhesive side is covered with a bandage so that it shall not stick. The upper arm is fixed to the chest by a circular bandage. Over this hangs the front end of the adhesive strip, which is made to end below in a sling to carry the forearm (Fig. 470). To this sling may be attached a 5-pound weight to coöperate with the forearm. When the patient lies down, weight and pulley extension may be substituted. Instead of using weight, a second adhesive strap may be attached to the front of the thorax and the two connected by elastic bands as described below.

Upward dislocation of the acromial end of the clavicle is easily reduced unless the bone is caught in the fibres of the trapezius muscle. This complication may require division of the fibers of the muscle. Usually reduction is easily effected by pressing the clavicle downward and the shoulder upward. The latter is accomplished by pressing upward upon the lower end of the humerus. Usually also after reduction is thus made, recurrence of the displacement takes place as soon as the pressure is removed. The indications for a permanent dressing are to continue these two lines of pressure and to hold the shoulder away from the chest toward which it tends to fall. It is not sufficient to carry a bandage or adhesive straps about these two points; some continuous increasing, not decreasing, pressure is required. This is best supplied as follows: Two adhesive strips, 5 cm. (2 inches) wide, are made to cross the outer end of the bone diagonally, one ending in front of the shoulder, the other behind. The free ends are folded under so that they do not adhere to the skin after passing over the clavicle. On the two free ends are sewed four hooks. Another adhesive strip is carried under the flexed elbow, ending in front and behind opposite the level of the upper border of the forearm. Four hooks are sewed to either end of this strip. The two ends above are connected to the two ends below by means of

rubber elastic bands, caught by the hooks. These bands need not be heavy; the combined pull of eight light bands suffices to give elastic pressure enough to keep the bone in place. The shoulder is prevented from falling inward by means of a good-sized pad in the axilla and a chest bandage holding the arm to the side. The forearm is supported in a sling (Fig. 471). Four weeks of this treatment, followed by simple confinement of the arm for two weeks more, usually suffice to effect a cure.

FIG. 470.—DRESSING FOR UPWARD DISLOCATION OF INNER END OF CLAVICLE.

The object of this dressing is to make downward pressure upon the inner end of the clavicle.

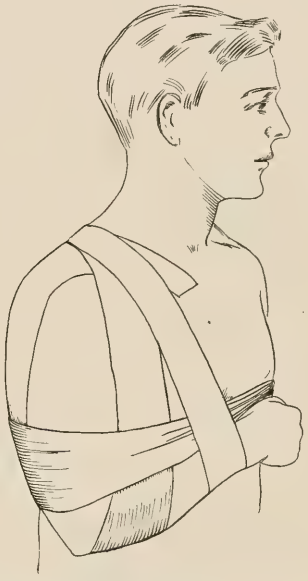


FIG. 471.—DRESSING FOR UPWARD DISLOCATION OF OUTER END OF CLAVICLE.

The object of the dressing is to make downward pressure upon the outer end of the clavicle.

If the ligaments do not grow together, and recurrence of dislocation takes place, the remedy lies in exposing the joint and suturing the torn or elongated ligaments, preferably by an overlapping suture, using chromic catgut.

Subacromial dislocation of the clavicle is reduced by drawing the shoulder strongly backward and outward, and at the same time pressing the clavicle forward. These efforts dislodge the clavicle from beneath the acromion, and permit it to ride up into position. A simple bandage should suffice to immobilize the shoulder by fixing the upper arm and forearm to the thorax.

Subcoracoid dislocation of the clavicle is to be reduced by drawing back the shoulder while the clavicle is grasped and pressed forward.

Backward dislocation of the acromial end of the clavicle is corrected by drawing the clavicle forward.

Simultaneous dislocation of both ends of the clavicle requires a combination of the treatments described for either end alone.

DISLOCATIONS OF THE SHOULDER

In treating these conditions the surgeon should have in mind the peculiarities of the joint. Some of these are the shallow glenoid cavity; the loose capsular ligament; the two overhanging processes of the scapula; the axillary artery and vein, passing between the head of the humerus and the thorax; the circumflex nerve, winding around behind the surgical neck of the humerus, and which is often damaged to the degree of causing deltoid paralysis; the circumflex and subscapular arteries which are put on the stretch in most dislocations, and may be torn from the main artery; and the fact that in nearly all dislocations the bone leaves the socket anteriorly, tears through the capsular ligament, and then takes a position somewhere along the anterior aspect of the head of the scapula, above, below or in the middle. In discussing the treatment of dislocations in general (page 610), the shoulder is taken as a type.

Anesthesia is usually not necessary for the reduction of recent dislocations of the shoulder. In nervous persons it may be used. Primary ether narcosis suffices. If there has been much pain, morphin may be given.

Anterior dislocations may be the common subcoracoid or the less common subclavicular. The chief opposition to reduction is furnished by the untorn part of the capsular ligament and by the contraction of the muscles. Reduction usually is not difficult. The resisting parts are best relaxed by abduction of the upper arm to relax the shoulder muscles and the lower part of the untorn capsule, flexion of the forearm to relax the biceps tendon, and external rotation to relax the posterior part of the capsule.

All clothing should be removed from the thorax and arm. An anesthetic is usually not required, but it may be used if, after one or two attempts, reduction fails. It is best to have the patient lie on a table with the dislocated shoulder at the edge, although sitting erect on a stool is a much used position. An assistant is of service. The surgeon should first establish a cordial relation with his patient; a good psychic atmosphere is more important than an anesthetic. Do not go at him too fast. Reassure him; solicit his coöperation; get him to relax his muscles; be gentle; and proceed deliberately and patiently to the reduction while the eye pierces the soft structures and watches the head of the humerus as it passes through the capsular rent into its socket. Reduction is recognized as it takes place with a click, or by the restoration of the normal contour and mobility of the joint. The old methods of pulling and hauling, without an intelligent appreciation of just what is being done, are crude, cruel and dangerous.

The natural method of reduction is to flex the forearm at a right angle, rotate the arm outward, and then while the arm is being abducted the hand grasps the upper part of the humerus or presses outward against the head to carry the bone through the rent, back to the glenoid socket. This outward rotation should be carried slowly as far as possible but not farther than 90 degrees. It relaxes the posterior part of the capsule and causes the rent to gap. If the head lies well internally, under the coracoid process or the clavicle, traction upon the humerus is necessary, combined with the movement of abduction, to cause the head to move outward. If the head, on the other hand, lies low down, in the axilla or below the glenoid fossa, it must be lifted up by pressure upon it or by grasping the humerus, to move it upward and backward. Usually it lies just against the anterior edge of the glenoid, and all that is required is to lift it back over the slight obstructing ridge and through the gaping opening in the capsule. When it is brought to the edge of the fossa, internal rotation should be combined with the outward pressure upon the upper end of the humerus.

Outward rotation and *adduction*, as advocated and practised by T. Kocher, of Bern, is one of the most successful of the routine measures. It is applicable to all anterior dislocations excepting the intracoracoid or subclavicular, and even in them it may be successful if strong outward pressure is made against the head. (1) The forearm is flexed at a right angle and the arm rotated outward about 90 degrees to relax the untorn posterior part of the

FIG. 472.—REDUCTION OF DISLOCATION OF SHOULDER BY METHOD OF KOCHER.
Outward rotation of arm; elbow carried to the side at *A*.

FIG. 473.—REDUCTION OF DISLOCATION OF SHOULDER BY METHOD OF KOCHER.
The arm has been rotated outward, the elbow pressed to the chest. In this picture the elbow is shown moving across the chest while the hand is carried toward the opposite shoulder.

capsule; the elbow is pressed to the side of the thorax (Fig. 472). This outward rotation should be continued slowly but persistently, overcoming resistance, until the great mass of the deltoid muscle is thrown out in a bunch. (2) The outward rotation is then maintained, and the elbow is carried across the front of the chest, keeping the elbow close to the anterior chest wall, and swinging it as far toward the other axilla as it will go (Fig. 473). The above described outward rotation with the elbow close to the side, while it relaxes the posterior part of the capsule draws tense the extreme lower part

of the capsule; this tension is now still more increased by swinging the arm inward across the chest; so great does the tension upon the lower band of the capsule become that as the elbow swings inward the head moves outward, rotating about this tense band as a fixed point, until it rides upon or against the anterior rim of the glenoid fossa. (3) The next step of the maneuver consists in quickly rotating the arm inward, bringing the hand upon the opposite shoulder. When this is done an assistant may encourage the head to move outward by pressing it toward the joint. The effect of this inward rotation is to add to the outward-moving tendency of the head the quick pull of the external part of the capsule and the tendons of the infraspinatus and teres minor muscles. As a result the head jumps into the socket.

I have applied this method of Kocher without anesthesia with immediate success in the great majority of cases. In some cases the head lay below, and internal to the coracoid process, and reduction has been accomplished easily by abduction to a right angle and outward traction. In one case in which the method has failed, lack of success was due to the fact that the lower part and perhaps more of the capsule were torn, because the manipulations failed utterly to cause the head to attempt to mount into the socket; when all that was required was to take hold of the upper end of the humerus with one hand, steady the scapula with the other, and simply lift the bone into place by pulling outward upon the arm. This last is a procedure so simple that it is much neglected, but I have found it applicable in many cases.

Downward and *outward traction* is applied by having counterextension made by the hands and arms of an assistant, embracing the chest, and with one hand in the axilla and the thumb pressing against the head of the humerus. In the absence of assistance a band may be passed round the chest and made fast to a fixed support. The surgeon flexes the forearm, grasps the arm above the elbow, and makes traction downward and outward, gradually raising the arm in abduction until, if necessary, a right angle is reached, at the same time rotating the arm outward. Abduction relaxes the shoulder muscles. Outward rotation relaxes the capsule and tightens the subscapularis, latissimus dorsi, and teres major muscles. The tight subscapularis prevents posterior displacement of the head. The combined result is that the head is drawn strongly outward and backward toward the socket. If it does not enter the socket, it may now be made to do so by outward pressure applied directly, or by inward rotation.

Instead of this an assistant may make the traction while the surgeon presses the head into the socket by drawing the upper end of the humerus outward and pressing the acromion inward. This is essentially the principle of the old *foot-in-the-axilla* method. Here the surgeon, in the absence of assistance, and the above methods failing, seats himself beside the supine patient lying on the floor, hitches a towel about the arm above the elbow, places his unshod foot in the axilla, and makes traction downward and outward. The head is pressed upward and outward by the foot. If this does not succeed, the arm may be brought down to the side while traction is still made, the foot acting as a fulcrum to give the head outward leverage. This method must be cautiously used as damage to the nerves and vessels may be inflicted.

The method practised by G. Schichhold (Mediz. Klinik, April 11, 1909) for forty years consists in the surgeon grasping the patient's forearm between his thighs as the surgeon stands in front of the seated patient. The surgeon's adductor muscles hold the arm, and as he pulls backward with his thighs he holds the patient's shoulder with his hands. This downward,

forward and outward traction, overcomes the muscles while the surgeon grasps the neck of the humerus with one hand and presses the head in place with the other. An assistant holds the patient in the chair by placing one arm around his neck and the other under the axilla.

Continuous right-angle traction is applied according to the method of A. Stimson. A round hole 15 cm. (6 inches) in diameter is cut about 45 cm. (18 inches) from the end in the middle line of a canvas cot. The injured arm is passed through this hole as the patient lies on his side, the cot being elevated upon four stools so that the hand hangs free of the floor. At the elbow or wrist by means of a soft towel is attached a weight of about 10 pounds. Because of the continuous traction, the muscles relax, and reduction takes

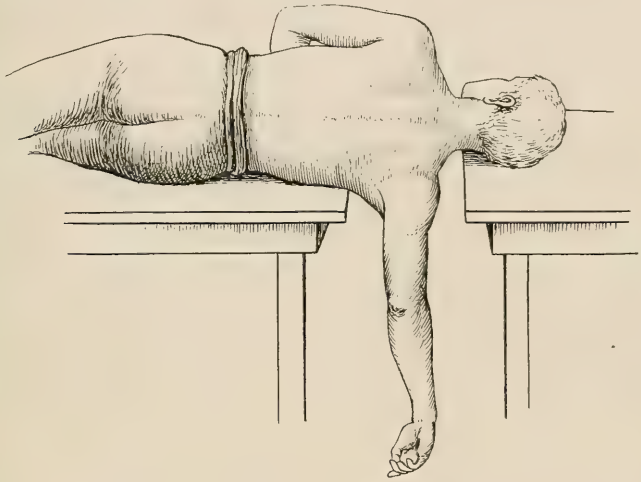


FIG. 474.—REDUCTION OF DISLOCATION OF SHOULDER BY GRAVITY.
If necessary a weight may be attached to the arm. Usually the weight of the arm alone suffices to effect reduction.

place in a few minutes—not more than six minutes being required in Stimson's experience. Instead of a cot the patient may be laid on two tables, separated a little over 15 cm. (6 inches) (Fig. 474).

Perpendicular traction is made in the opposite direction from the above. The patient lies on the floor; an assistant stands on a stool, grasps the arm above the elbow and makes traction, if necessary lifting the patient from the floor; while the surgeon presses the head of the bone backward into place.

The *fulcrum method* is effective in most cases. The object of all methods of reduction must be to lift the head, over the glenoid rim, back into the socket. This may be done by placing a roll of gauze, towels or cotton about 10 cm. (4 inches) thick in the axilla, held by a band passed across the opposite side of the neck, and pressing the elbow against the side of the body. As this is done, the elbow is lifted slightly forward, and the arm rotated lightly outward. If muscular resistance develops the movements should be stopped until the muscles relax. The head jumps into the socket with a jerk.

Obstacles to reduction may be present to hinder the success of any of the above methods. The capsule may be interposed in such a way that these manipulations fail. The opening may be so small that the head instead of

passing back through it, pushes the capsule in front of it. A fold of the capsule may be turned back and lie in the glenoid fossa like a valve, reduction taking place upon it. The tendon of the biceps or subscapularis may be interposed and the head fail to pass round them. These conditions call for arthrotomy and reduction by the aid of sight.

Old anterior dislocations should not be treated by any of the forcible methods. The natural method or traction downward and outward may be cautiously applied, carefully increasing the excursions of the bone, and gently massaging the axillary structures away from the head. Operative treatment is the safest and most certain.

The *after-treatment*, following any reduction, should consist in immobilization for three weeks with the arm rotated inward. This is accomplished by putting on a bandage, fixing the forearm acutely flexed across the chest, the hand below the opposite clavicle, and the upper arm close to the side (see Bandages). After healing of the ligaments, passive motion, massage and gradual use of the joint are to be instituted. Too early use of the joint, before the torn parts have healed, is responsible for permanent relaxation and recurrence of displacement.

Downward Dislocations.—*Subglenoid dislocations* are rare. The head of the humerus is displaced downward upon the tendon of the long head of the triceps, under the inner edge of the glenoid fossa, or between the latissimus dorsi and teres major muscles. The danger of injury to the vessels is great. Reduction should be attempted by passing the hand around the upper end of the humerus, pressing the lower end of the humerus inward, and lifting the upper end outward. If the elbow comes easily against the side adduction may be carried still further by bringing the arm behind or in front of the chest. As a last resort traction may be combined with abduction. This last method has been successfully employed, but it theoretically offers the greatest danger to the vessels.

Erect dislocations, in which the head is driven downward while the arm is erect, leaving the humerus directed upward, are reduced, naturally, by upward traction upon the dislocated member, causing it to ride back into the joint by the route by which it passed out.

Posterior dislocations, in which the head lies on the posterior surface of the scapula below the acromion or spine, are naturally reduced by making outward pressure upon the head and outward traction upon the arm, combined with slight rotatory traction upon the arm, and with slight rotatory movements to free the bone from entanglements. This is a dislocation the reduction of which need not endanger the vessels or nerves of the axilla, provided the lower end of the humerus is swung inward or forward, to relax the axillary structures and untorn part of the capsule, as reduction is made.

Upward dislocation, an extremely rare condition, is to be reduced by downward traction upon the humerus, with slight rotary movements and pressure upon the head. By keeping the arm close to the body, damage to the vessels need not be feared. Fracture of the coracoid, complicating the dislocation, requires the treatment already laid down for that condition.

The **after-treatment** of these rarer forms of dislocation should be immobilization of the joint for three weeks, with pads or pressure appropriately applied to meet any peculiar conditions present. Thus in downward displacement, in addition to immobilization, the elbow should be well supported after the manner recommended in upward dislocations of the outer end of the clavicle. In backward dislocations, it may be necessary to place a pad back of the upper end of the humerus to press forward while the elbow is

carried slightly backward and outward. In upward dislocations harm may be done by supporting the elbow. The anatomical conditions call for downward traction just as in fractures of the upper end of the humerus. Otherwise these injuries are to be treated the same as the common anterior displacements.

Complicating injuries have been spoken of in discussing dislocations in general (page 610), but the complications in shoulder dislocations are of sufficient importance to receive special consideration.

Rupture of muscles and tendons is frequent. Laceration of the subscapularis, common in inward dislocations, heals best with the arm immobilized close to the chest and rotated inward. Rupture of the tendons, attached to the greater tuberosity, or tearing off of the tuberosity are matters of such importance for the future strength of the shoulder that exposure by incision and suture of the parts are the best treatment.

Fracture of the anatomical or *surgical neck* is not an uncommon complication of dislocation. Of it Sir Astley Cooper said, "Every intelligent, well-informed surgeon will now confess that no knowledge or exertion of skill could have prevented the deformity and loss of the natural motion which results from this formidable accident." The loss of leverage because of the fracture leaves the upper fragment in a condition difficult to control. The higher the fracture, the greater the difficulty.

In the anterior dislocation, reduction should be attempted by outward traction upon the arm in the abducted position, while an effort is made to press or manipulate the head into place. This method should be given a faithful trial under general anesthesia. Diagnosis has a most important relation to treatment because manipulations, such as that of Kocher's method, can only do harm. In perhaps half of the cases reduction can be effected without a cutting operation. The treatment after reduction is the same as that for fracture.

In the event of failure of reduction it was customary prior to 1894 (1) to secure a false joint at the fracture, (2) to secure union of the fracture and then attempt reduction, or (3) to cut down upon the joint and remove the upper fragment. All of these methods gave poor results, and prompted the expression quoted above from Astley Cooper. C. McBurney in 1894 applied the modern surgical treatment. The operation consists in exposing the fracture by an external or anterior incision between the fibres of the deltoid muscle, retracting the parts to expose the upper fragment, boring a hole in it with a drill, inserting a hook in the hole, and drawing the head of the bone into its socket (McBurney: Annals of Surgery, vol. 19, 1894, and vol. 23, 1896). The hook is strong, made in the shape of an L, and having a big handle for grip and leverage. The hole should be just the size to receive the hook. While traction is made upon the bone, pressure is also made upon the head, and an assistant makes counterpressure upon the scapula. McBurney also advised, if necessary, the insertion of a similar hook in the middle of the spine of the scapula to make counter traction. The dislocation having been reduced, there remains the fracture, which should be treated the same as any fracture of the neck. It seems needless to say that rigorous asepsis is essential. The operation has been used in both fractures of the surgical and anatomical necks with most gratifying results.

Fracture of the shaft of the humerus, as a complication of dislocation, is not so difficult to manage as fracture of the neck; but if reduction is impossible because of failure of traction or leverage, the use of McBurney's hook through a small wound midway between the fracture and the joint is called for.

Fracture of the scapula, whether of the coracoid or acromion, calls for the treatment already given for these parts, after reduction of the dislocation. Fracture of the glenoid may be overlooked. If the separated fragment is sufficiently large, it will cause the head of the humerus to slide out of place with it. This condition calls for a pad to make firm pressure upon the head on the side toward which the displacement occurs.

Injuries to nerves and *vessels* have been discussed (see page 611).

The chest wall has been penetrated by the head of the humerus. In the event of such an accident, if outward traction does not release the bone, operative exposure should be done and the necessary rib resection performed to permit its release.

Compound dislocations should be treated according to the rules already laid down (page 612) and with the same precautions as are applied to the treatment of compound fractures (page 518).

Habitual dislocations, due to relaxation or elongation of the capsule, fracture of the head or anatomical neck of the humerus, fracture of the glenoid cavity, tearing of tendons or muscular insertions, or pathologic changes of the shape of the head of the humerus, are not uncommon. Following dislocations, if immobilization is not maintained sufficiently long, recurrence takes place; and every recurrence makes the succeeding one easier. This is particularly true in the dislocations of epilepsy.

Treatment by apparatus is to be rejected as vicious, because it increases the weakness of the muscles and ligaments. Massage, exercise and efforts to improve the circulation and nutrition are sometimes effective. The shoulder muscles may be made larger and stronger. The muscles especially requiring exercise are the subscapularis, posterior scapular muscles, deltoid, biceps, triceps and coracobrachialis. Recurrence should be treated by reduction, immobilization and support of the humerus, but the shoulder should be left exposed and daily massage of the muscles applied for two or three weeks before motions are again allowed.

These measures failing, *operation* is called for. If the cause of the recurrences is known it should be attacked at once; but always an elongation or relaxation of the capsule will require treatment whether there is any other cause or not. Distortion of the head of the humerus may be treated by osteotomy and fixation of the bone in corrected position. The same is true of distortion of the glenoid cavity following viciously united fracture; or its cartilaginous edge may require to be repaired. If it is discovered that the biceps tendon is torn away, or the tendons attached to the tuberosities, they should be liberated from their adhesions, brought into place, and fixed at their normal insertions (see operations on Muscles and Tendons).

The tightening of the capsule is always called for if after two or three months of treatment dislocation still takes place. For the relaxation following anterior displacements, the following operation may be done: The capsule is exposed by an incision carried downward from the coracoid process to a point just below the upper border of the tendon of insertion of the pectoralis major. The cephalic vein is retracted outward and the space between the deltoid and pectoralis major opened. The upper half of the insertion of the pectoralis major is divided, and the parts widely retracted. The long head of the biceps is felt at the outer part of the wound running into the capsule. The short heads of the biceps and the coracobrachialis are discovered at their coracoid origin. The head is felt external to these two muscles. The arm is rotated outward, and the subscapularis brought into view as it passes in front of the capsule to reach the lesser tuberosity. Its upper half is cut to expose more freely the anterior aspect of the capsule. The relaxed

capsule is cleared of loose connective tissue and grasped with mouse-tooth clamps. A fold is taken up in the direction of greatest relaxation and excised. The arm being rotated outward means that the anterior part of the capsule will be still more relaxed when rotation inward is made, and this fact should be considered in making the excision. Sutures of chromic catgut are used. The best union is secured by making an overlapping suture, serosa against connective tissue. An elliptic piece may be removed, the sutures inserted in the farther side, the arm rotated inward, and the sutures passed in the nearer side (Fig. 475).

In this operation, the acromial branch of the acromiothoracic artery is divided. The cut fibers of the pectoralis major and the subscapularis may be sutured as the arm is adducted. Still more room may be secured by carrying an incision backward from the upper end of the coracohumeral incision, and separating the deltoid from its clavicular origin. Instead of cutting the subscapularis it may suffice to free it from its adhesion to the capsule by blunt dissection; or it may be completely divided.

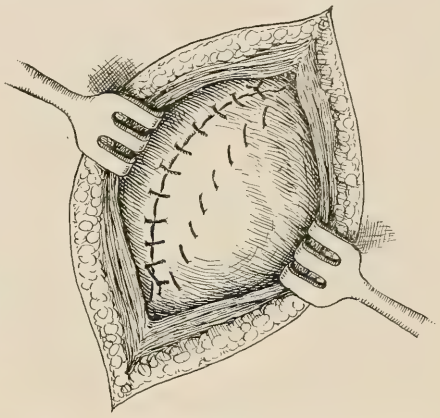


FIG. 475.—SHORTENING JOINT CAPSULE IN THE TREATMENT OF HABITUAL DISLOCATIONS OF THE SHOULDER.

The joint has been opened and the wound closed by overlapping the capsule with a double row of sutures.

Another method of approach is by a curved incision along the anterior border of the axilla. The arm should be abducted to a right angle. The incision follows the lower border of the pectoralis major and then passes along the inner border of the coracobrachialis muscle. The incision should be about 20 cm. (8 inches) long. The coracobrachialis, biceps and pectoralis muscles are retracted upward and outward and the axillary vessels and nerves are retracted inward. The anterior circumflex vessels are divided. The posterior circumflex vessels need not be injured. The circumflex nerve is identified and protected as it passes backward with the posterior circumflex nerve behind the artery at the lower border of the subscapularis muscle. The latissimus dorsi muscle lies at the depth of the wound. By rotating the arm outward the insertion of the subscapularis comes into view. Enough of the width of the subscapularis muscle is then divided to expose the capsule of the joint. This may require division of half or the whole of the muscle. The joint is opened by a curved incision 4 or 5 cm. (1½ or 2 inches) long at the extreme lower and front part of the joint. This incision follows the glenoid margin, and is transverse to the direction of the fibers of the capsule. The head is replaced in the socket, and with mattress sutures of No. 3 chromicized catgut the capsule of the joint is caused to overlap the opening thus made and shorten it sufficiently to hold the head in place. It will often be found that the capsule is ruptured at its lower part, and the operation repairs this rupture. If a thinned part of the capsule is discovered, this is the place of rupture, and the overlapping operation should be done here. The repair should be made with the arm abducted to a right angle with the body. Later stretching exercises will lengthen the shortened capsule to its physiological limit.

For habitual and recurring subcoracoid dislocation of the shoulder Allis suggested dividing the lower half of the insertions of the tendons of the pectoralis and latissimus dorsi and keeping the shoulder elevated for ten days until union has occurred. The tendons are exposed by an incision between the deltoid and pectoralis major. In thin persons the tendon of the latissimus dorsi can be hooked up through this incision, but in muscular persons it will have to be exposed by a second incision along the posterior border of the axilla.

Dislocations due to paralytic nerve lesions are best not treated by these measures. For the constant dropping of the head from the socket, arthrodesis offers the best aid.

Old unreduced dislocations have been discussed in general (page 612). In the shoulder they are not uncommon, and require the best judgment of the surgeon. Immediate operative reduction is called for in a recent dislocation which does not yield to the ordinary methods. Operation should not be delayed until irremedial changes have taken place. A dislocation of the shoulder may be called old after three months. Before that time the experienced surgeon may attempt reduction by the ordinary manipulations. If the case is near the three months' limit, everything should be in readiness for operation in the event of rupture of the axillary vein.

In old cases operation is called for to improve function and relieve pain, and less commonly to improve the circulation and nerve impulse transmission. In anterior dislocations, the incisions of choice are those described above for operations for habitual dislocations. The dislocation is best exposed between the two heads of the biceps. The inner head and the coracobrachialis are retracted inward with a blunt retractor. Often by lifting forward these two muscles, and liberating some adhesions reduction can be accomplished. If the dislocation is so old that the capsule has become adherent to the glenoid cavity, this should be freed. After incising the capsule, exposing the head, and preparing the glenoid for its reception, reduction can be made. If reduction cannot be effected excision of the head is indicated. This is accomplished by stripping back the periosteum from the tuberosities with its attached muscles, passing a flexible saw around the bone just below the tuberosities, sawing through, completing the denudation of the head of its muscular attachments, dissecting it free from its adhesions, taking pains to keep close to the bone, and removing it. It should not be dragged upon, but rotated out. As many of the muscular insertions as possible should be preserved connected to periosteum. The upper end of the bone should be placed in the glenoid cavity. If possible the insertions of the muscles into the tuberosities should be preserved and reattached to the upper end of the bone. The capsule should be sutured about the upper end with the view of preserving a joint.

Congenital dislocations, due to irregular development of the joint to traumatic dislocation at birth, and to paralysis caused by nerve injury at birth or to some other nerve disorder, may all be helped to a greater or lesser degree. The first two forms may be corrected by manipulation, held immobilized for a few weeks, and often cured. If not amenable to this treatment, operative exposure by an arthrotomy incision is called for, and treatment applied to the condition found. The anterior incision is best. Paralytic dislocations require treatment of the nerve injury. If the paralysis is due to an incurable nerve disease, the joint may be exposed and ankylosis produced.

Paralytic dislocations have been discussed in several of the above paragraphs, especially under the head of *habitual dislocations*. It is possible in

some of these cases to expose the joint, remove the articular cartilage, destroy the lining of the capsule with iodin, tightly suture the capsule so as to secure bony union between the humerus and scapula, and depend upon the muscles which move the scapula to move the arm.

Pathologic dislocations have been described under *spontaneous dislocations.*

DISLOCATIONS OF THE ELBOW

Correct diagnosis is such an important matter in elbow injuries that it may properly be spoken of as a part of the treatment. Treatment is greatly facilitated by an identification of the positions of the three important landmarks—the two epicondyles and the tip of the olecranon. The *x*-ray is of great service, as it can show the relations of bones which the fingers cannot detect. Failure to recognize this injury, or to treat it for something else, is responsible for many crippled arms.

Dislocation of the forearm backward is the common dislocation at the elbow. The reduction is not difficult. As the anterior ligament is torn, extension is easily made. The forearm should be slowly extended until it is in a line with the upper arm. If extension to this point is easy, it may be carried to slight hyperextension. The forearm should then be grasped at the wrist while counterextension is made at the humerus, and the arm drawn downward in the direction of its long axis. Slight backward pressure should be made upon the upper part of the forearm and forward pressure upon the lower part of the humerus to cause the coronoid process to ride over the articular process of the humerus. After it has passed the end of the humerus the elbow may be flexed, and the reduction is complete. The arm should be put up flexed at an angle slightly smaller than a right angle, and kept immobilized for two or three weeks.

The old practice of flexing the elbow at a right angle, making traction in the direction of the long axis of the humerus, and drawing the forearm forward is objectionable. Still worse is the method of grasping the lower end of the humerus and drawing the forearm forward at a right angle. (This is the *reductio ad absurdum.*) Neither of these methods takes advantage of the relaxation caused by the torn anterior ligament, nor do they relax either the posterior or anterior groups of muscles. In reducing thus at a right angle, it is necessary to cause the forearm to move downward more than 1.25 cm. (½ inch) lower than normal, for this is the length of the coronoid process which must ride under the trochlea. If reduction is made in the straight position, a little backward pressure or hyperextension disengages the coronoid process from the olecranon fossa, and causes it to pass on under the trochlea without tearing any more ligaments.

Complications sometimes add difficulties to the treatment. Dislocations more than a week old are apt to present *adhesions* which require to be broken up by passive motion in all directions before reduction can be made. *Fractures* of the coronoid or olecranon require the treatment already laid down for these lesions. Fracture of the head of the radius, of the epitrochlea, or of the condyles also require their own special treatments. The injuries to vessels and nerves have been discussed (page 611), as have *compound dislocations* (page 612).

Incomplete inward dislocations are those in which the bones of the forearm are displaced inward, the head of the radius is in contact with the trochlea, and the ulnar articular surface is partly or wholly internal to the trochlear surface. Reduction is accomplished by traction upon the forearm in the extended position combined with lateral pressure. If the outer edge of

the ulna engages against the humerus and prevents lateral replacement, leverage may be secured by outward lateral flexion; this combined with traction and outward pressure should effect reduction.

Incomplete outward dislocations are characterized by a displacement of the radius from its capitellum while the ulna passes outward and its sigmoid notch embraces the capitellum. The radius usually lies below the external epicondyle. Reduction requires that the sigmoid surface of the ulna shall be drawn away from the under surface of the humerus sufficiently to slide inward. If this is accomplished the head of the radius easily follows it. Longitudinal traction should be made while the bones are pressed inward. If this does not suffice, outward flexion may be added to the manipulations, provided the radius rests against the under surface of the condyle as a fulcrum. Hyperextension may be of help. By carrying hyperextension far enough the dislocation is converted into a posterior one, the reduction of which may be more easily performed.

Reduction in a recent case should not be difficult, provided that the capitellum is not broken off. When this complication is present the displaced fragment may engage the bones in a tilted position and prevent their passage inward. Manipulation then failing the fragment may easily be removed through a posterior-internal incision.

Complete outward dislocation means that both the radius and ulna have passed outward until the articular surface of each has gone beyond the epitrochlea of the humerus. The sigmoid notch may embrace the epicondyle, looking forward, or it may be pronated until the radius is anteriorly and the sigmoid looks inward; or the sigmoid notch may have passed around the external epicondyle, and both radius and ulna lie above the condyle. To cause these complete dislocations the ligaments have been so torn and stretched that reduction is not difficult although the distortion is great. Downward traction and inward pressure upon the upper end of the forearm bones should suffice. Engagement of the head of the radius or the olecranon between muscular or fascial bands may require some manipulation. Naturally the bones should retrace their course, the complete dislocation being converted into an incomplete one, by causing the sigmoid to ride back around the condyle.

Forward dislocations are characterized by a riding downward and forward of the ulna, carrying with it the radius, until the top of the olecranon rests against the articular surface of the humerus. Reduction is effected by pressing the upper end of the ulna backward. This motion is facilitated by making flexion of the forearm at the same time.

Anteroposterior dislocations involve a rotation of the forearm so that one bone is displaced backward and the other forward. Treatment is by traction in the direction of the long axis of the ulna and pressure upon the head of the radius to force it into place. Supination or pronation may be required in addition.

Transverse dislocations are those in which the radius is dislocated outward and the ulna inward. Reduction is made by traction and by pressing the two bones together. Lateral flexion may be used to take advantage of the leverage of one bone to liberate the other. As in the above dislocation, the torn orbicular ligament may prevent complete reduction of the radius upon the ulna.

Backward dislocation of the ulna alone is characterized by a rotation backward and outward of the ulna around the radius, then adduction of the forearm takes place, and the upper end of the ulna slips back of the humerus. The sigmoid notch looks inward. Reduction is effected by

supination of the forearm, extension and abduction. If the coronoid process does not promptly ride under the humerus, it may be made to do so by hyperextension and traction in the direction of abduction. In an old unreduced case of this dislocation which I exposed by incision, it was very evident that reduction could have been done had these manipulations been made when the dislocation was recent.

Inward dislocation of the ulna alone is to be treated by traction, abduction of the forearm and outward pressure upon the dislocated bone.

Forward dislocations of the ulna alone are to be treated by traction, pronation, backward pressure upon the ulna, and adduction of the forearm.

Backward dislocations of the radius alone are to be reduced by traction, forward pressure upon the head of the radius, and adduction of the forearm.

Outward dislocations of the radius alone are to be reduced by adduction of the forearm and inward pressure upon the head of the radius.

Forward dislocations of the radius alone are to be reduced by making traction upon the forearm, adduction and backward pressure upon the head of the radius. If this does not succeed flexion may be substituted for extension. Complete reduction may be hindered by interposition of the orbicular ligament. As in the treatment of fractures of the upper end of the radius, to lessen the tendency to forward displacement caused by the biceps, the arm should be put up in acute flexion.

Subluxation of the head of the radius by traction, seen in young children as a result of lifting them by the hand or wrist, is probably a partial downward dislocation, with separation from the capitellum and a partial escape from the orbicular ligament. Reduction is effected by supination and flexion.

Complications of dislocations at the elbow are many. *Fracture* of the *olecranon*, occurs most commonly in forward dislocations, and requires treatment with the arm in the straight position. Fracture of the *coronoid* process requires treatment in the flexed position. Fracture of the neck and head of the *radius* may occur in any of the dislocations of that bone in which the radius rides against the humerus. *Fracture* of the shaft of the *ulna*, associated with *dislocation* of the head of the *radius*, is not an uncommon combination, and often results badly because of failure to discover the dislocation. In all of these conditions, the dislocation should be reduced and then the fracture given attention.

Compound dislocations of the elbow require no special treatment beyond that already given (page 612).

Old unreduced dislocations of more than six weeks' standing can rarely be reduced without operation. The older the dislocation, the greater the difficulty. Reduction is prevented by torn capsule healing in abnormal relations, muscle or fragments of bone interposed, exostoses resulting from stripping up of periosteum on the back of the condyles, adhesions and new connective tissue growing to the articular surfaces, and developmental distortions of bone in growing children.

In the common *posterior dislocation* of both bones, operation offers much. One proceeds as follows: An incision is made external to the head of the radius, exposing the radius and posterior aspect of the outer condyle. Exostoses are removed by the chisel, and the capitellum and head of the radius freely exposed by dividing the adhesions. The sigmoid fossa of the ulna is also cleared of fibrous tissue. Another incision, 10 cm. (4 inches) long, is then made on the inner side of the olecranon. The ulnar nerve is retracted forward, the trochlea and the sigmoid fossa cleared. Attachments of the olecranon to the back of the humerus must be divided, and then reduction can be accomplished. In very old dislocations, contractions of the forearm

muscles may prevent reduction, in which event they must be divided close to the humerus. Any vicious union of old fractures should be corrected by osteotomy and replacing the fragment.

In old *lateral dislocations* the same principles apply: lateral arthrotomy incisions, freeing of the parts from adhesions, division of resisting structures, removal of abnormal bony prominences, and reduction. The ulnar and musculospiral nerves should be guarded from injury. In dislocations of the *radius* alone, the bone should be exposed, the musculospiral nerve protected, and the orbicular ligament prepared for the reception of the head.

In children, old dislocations remove the normal pressure from the ends of the bone and cause more rapid longitudinal growth; this results in distortions which often make reduction impossible without removal of bone. Such cases call for such operations as osteotomy and correction, excision of bone, removal of the head of the radius, etc.

In a case of backward dislocation of the upper end of the ulna alone of six weeks' standing, in a twelve-year-old boy, with rotation of the ulna about the radius so that the sigmoid notch looked inward, and with almost immovable fixation, I made an incision along the inner side of the olecranon, and found that reduction was easy as soon as an exostosis was chiseled off from the posterior aspect of the inner condyle. The result was a perfect restoration of function (Annals of Surgery, vol. 52, page 215).

Pathological dislocations should be treated by giving attention to the condition which produced the dislocation and then to the dislocation itself.

DISLOCATIONS AT THE WRIST

Dislocations of the lower end of the ulna, whether backward or forward, are easily reduced by pressure upon the bone, aided by counterpressure upon the lower end of the radius.

Backward dislocations of the wrist should not be confused with fracture of the radius and backward displacement of the lower fragment. It may be associated with a chipping off of the posterior lip of the lower end of the radius, or the semilunar bone may remain attached to the radius while the rest of the carpus is dislocated. These possibilities should be had in mind. Reduction is usually easily accomplished by making traction upon the hand and forward pressure upon the wrist.

Forward dislocations of the wrist are easily reduced by traction upon the hand and backward pressure upon the wrist.

Lateral dislocations of the wrist are to be treated by traction upon the hand and direct pressure in the direction of restoration. Occasionally a single carpal bone, which can not be restored to position, must be removed.

Spontaneous subluxation of the wrist, that condition found especially in people between fifteen and twenty years of age who use their hands much in heavy work, and characterized by gradual relaxation of the ligaments, forward displacement, and increased downward growth of the posterior lip of the lower end of the radius, should not be mistaken for traumatic dislocation. The carpus should be held back in normal position by a splint of leather and the hand should continue to be used. It is found that when the bones cease their growth, if the carpus is kept back in place, the equalization of pressure corrects the deformity.

DISLOCATIONS OF THE CARPAL BONES

Backward dislocations of the mediocarpal joint are corrected by extension and pressure, with dorsal flexion if necessary.

Forward dislocations of the mediocarpal joint are to be reduced by traction, backward pressure and palmar flexion if necessary.

Dislocations of the individual carpal bones may involve any of these structures. Usually the displacement is backward. Correction is to be made by efforts to widen the mouth of the opening from which the bone escaped, and then to press the bone into place. Thus in anterior displacement of the semilunar bone, hyperextension of the hand should be made, the bone pushed backward, and then while pressure upon the bone is continued the hand should be flexed. Posterior dislocations may be reduced by flexing the hand, making traction upon the three fingers below, and pressing the bone into its place; after the bone is engaged, strong pressure should be continued, and extension substituted for flexion of the hand.

Failure to reduce these dislocations of individual bones, should be followed by excision of the bone. The operation is not called for in the event of partial dislocations which are giving no pain or disturbance of function.

DISLOCATIONS OF THE CARPOMETACARPAL JOINTS

There may be forward or backward dislocation of one or more metacarpal bones. Reduction is effected by traction and direct pressure.

DISLOCATIONS OF THE THUMB AND FINGERS

The dislocations of the phalanges from the metacarpal bones and of the phalanges from one another are among the most common of all dislocations.

Dislocations of the proximal phalanx of the thumb are incomplete and complete. The former are easily reduced by slight traction, extension and pressure.

Complete backward dislocations are among the difficult cases. The head of the phalanx has ridden backward and upward, and is prevented reduction by the interposition of sesamoid bone, the torn anterior ligament drawn under the head of the metacarpal bone, the tension of the tendon of the flexor longus pollicis embracing the neck of the metacarpal bone, the embracing of the head of the metacarpal bone between the two heads of the flexor brevis pollicis, button-holing of the head between the lateral ligaments, and the tension of all of the thumb muscles upon the ligamentous structures of the joint. Whichever of these causes is dominant, reduction is often difficult.

Correction is best accomplished by making palmar flexion of the metacarpal bone to relax the flexor muscles, the hyperextended thumb should be moved into its normal antero-posterior plane, the extension should be maintained while the proximal end of the phalanx is pressed downward into the joint, if necessary the hyperextension may be increased to permit this, and as soon as the phalanx has passed back around the lower end of the metacarpal bone it should be flexed. Manipulation in a certain percentage of cases will fail. When it does, operation is to be preferred to violence. An incision should be made on the palmar side midway between the flexor and extensor tendons. Through this the obstacle to reduction can be discovered. Tendons may be retracted, folds of ligament removed, or obstructing hands divided. The results of operation are good. In old unreduced dislocations, if reduction is not to be effected by the above means, excision of the head of the metacarpal bone is called for. This also gives a good functionating thumb, and has been resorted to in some cases of recent dislocation.

Forward dislocations are reduced by traction, combined with flexion and direct pressure.

Dislocations of the proximal phalanges of the fingers are best reduced by the same methods as described for the thumb.

Phalangeal dislocations are reduced by traction and direct coaptation pressure, combined with hyperextension in posterior dislocations and flexion in anterior dislocations. Traction directly in the line of the long axis of the finger is decidedly objectionable, because more strain is put upon the lateral ligaments than when extension or flexion is employed.

DISLOCATIONS OF THE HIP

Dislocations of the hip require for intelligent treatment an understanding of the anatomy of the joint. The peculiar features are the deep situation of the joint, being covered by thick masses of muscle; the deep acetabulum,

FIG. 476.—ILIOFEMORAL LIGAMENT OF HIP-JOINT.

This ligament is a most important factor in reducing dislocations of the hip, and the surgeon must have it in mind while making the reduction.

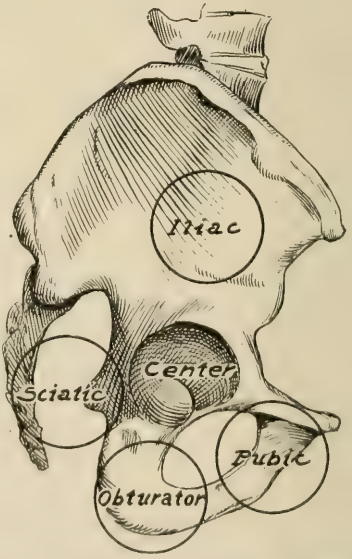


FIG. 477.—POSITION OF HEAD OF FEMUR IN VARIOUS DISLOCATIONS OF HIP.

with its elevated borders, which receives the head of the femur; and finally the ilio-femoral or Y-ligament of Bigelow (Fig. 476) passing in front of the joint from the anterior-inferior spine of the ilium to the whole length of the anterior intertrochanteric line. This strong ligament suspends the femur when dislocation takes place, and it is around this that the neck and head swing and are restrained in the movements of dislocation and reduction.

For convenience, the dislocations are divided into groups depending upon the location of the head and the manner of its leaving the joint. They are (1) *backward dislocations* (dorsal, iliac, sciatic, everted dorsal), (2) *downward*

dislocations (obturator, ischiatic, perineal), (3) *forward dislocations* (pubic, suprapubic,) (4) *upward dislocations* (supracotyloid), (5) *central dislocations* (inward through the fractured floor of the acetabulum) (Fig. 477). It is important that the surgeon should recognize the dislocation with which he has to deal in order that he may cause the head to retrace its path back into the joint. The Y-ligament, he may assume is untorn, and the head has usually either swung around in front or behind it. Usually the head leaves the socket posteriorly or below, and the course it then takes depends upon the position of the thigh. Reduction is best accomplished with the patient under the influence of a general anesthetic.

FIG. 478.—REDUCTION OF POSTERIOR DISLOCATION OF HIP BY MANIPULATION.

First Step: The pelvis is firmly held by an assistant; the thigh and leg are flexed at right angles; and the limb is strongly drawn forward while adduction of the thigh is maintained.

Dislocations backward were once treated by powerful traction. Nathan Smith and Henry J. Bigelow placed the treatment upon a scientific basis, and introduced in modern surgery the method of reduction by manipulation.

Bigelow's method is as follows: With the patient on his back, and the pelvis firmly held, (1) the knee is flexed, the thigh is flexed to a right angle, while the adduction and inward rotation are maintained; (2) traction for-

ward is then made to cause the capsule to become tense and to move the head to the edge of the acetabulum (Fig. 478); this is followed by (3) outward rotation and abduction (Fig. 479) as the limb is brought down straight (Fig. 480). Briefly in Bigelow's own words: "(1) Flex and forcibly lift. If this fails, (2) flex and lift while abducting. If this fails, it will be found that the rent in the capsule has been so enlarged that the first method may now prove successful."

In these manipulations, inward rotation relaxes the capsule and lifts the head from the surface of the pelvis; flexion of the thigh and preserving the inward rotation and adduction carry the head downward and forward to the edge of the acetabulum; forward traction, or lifting the pelvis in recumbency,

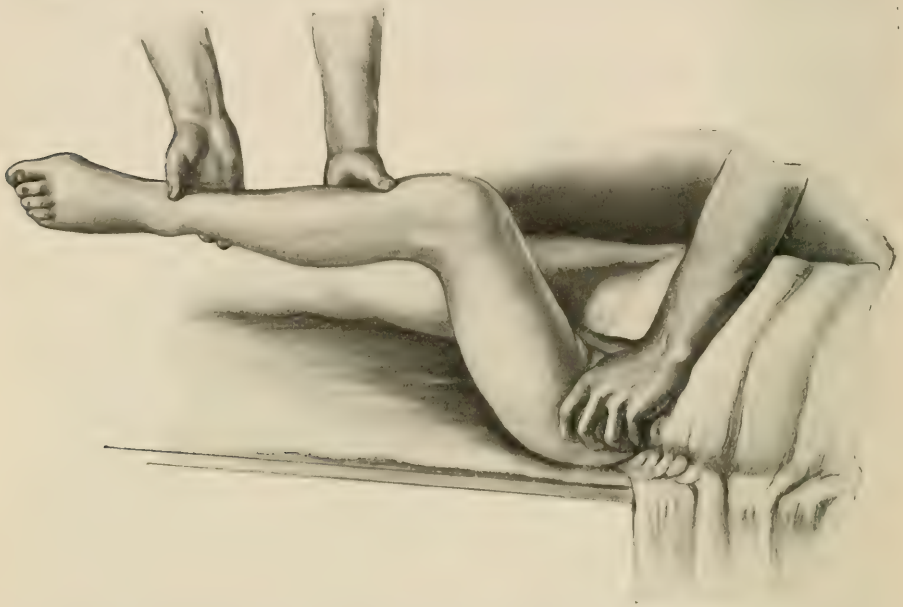


FIG. 479.—REDUCTION OF POSTERIOR DISLOCATION OF HIP BY MANIPULATION. Second step: The pelvis is firmly held and the flexed thigh is abducted and rotated outward.

causes the capsule to become tense, and holds the head at the acetabulum; and, with the parts held in this condition, outward rotation now causes the tense posterior part of the capsule and the Y-ligament to act as a fulcrum around which the head rotates into the joint as the limb is brought down. External rotation must be avoided during the first steps of the manipulation lest it throw the head forward above the acetabulum and produce an everted dorsal dislocation. It is also important that when flexion and abduction are made, forward traction shall be maintained in order to prevent the head passing back below the socket into the obturator foramen.

In some cases the pelvis is best steadied by placing the patient on the floor and screwing three screw eyes in the floor, one on either side of the pelvic brim, the other at the perineum. Through these a wide bandage is passed to hold the pelvis. In the case of muscular patients the surgeon may have to place his foot upon the anterior-superior spine while making traction and rotation, or in order to make traction sufficiently strong he must connect a bandage above the knee and lift by carrying it over his shoulders, leaving his hands free to perform the final outward rotation.

L. A. Stimson's method, described by him in 1889, consists in placing the patient face downward upon a table with his groins at the end of the table. The thigh of the injured side hangs flexed at a right angle over the table while the surgeon grasps the ankle and supports the leg flexed at the knee. The other leg lies on another table or is held horizontally by an assistant. The weight of the limb makes the necessary forward traction, and the surgeon waits for the muscles to relax, while he makes a slight rocking motion of the limb. A small sand bag may be laid at the knee to increase the traction (Fig. 481). This method, said Stimson, will often succeed without an anesthetic, "and sometimes so quietly that there is no jar or sound indicating the return to place."

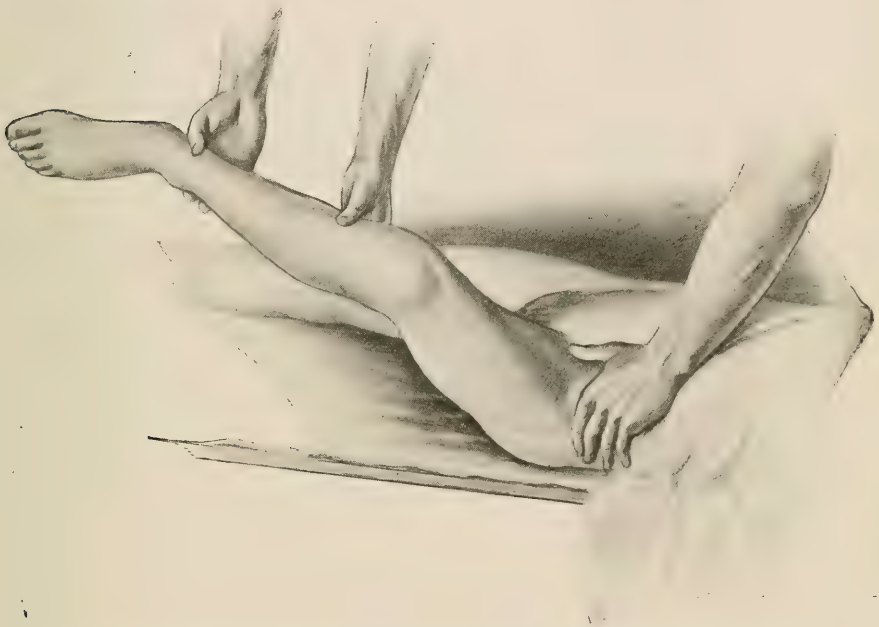


FIG. 480.—REDUCTION OF POSTERIOR DISLOCATION OF HIP BY MANIPULATION. Third step: The pelvis is held, the flexed thigh is rotated outward, and then the limb is drawn down straight.

Everted dorsal dislocations present a high position of the head with strong outward rotation of the thigh. They should be converted into the simple dorsal form. Flexion, inward rotation, and adduction of the thigh accomplish this. If the Y-ligament has been ruptured, its assistance in throwing the head in by outward rotation is lost, and reduction must be effected by traction forward and by manipulation.

Dislocations downward and inward are commonly of the *obturator* variety. Reduction is accomplished, usually without difficulty, by the method worked out and applied by Bigelow. This consists in flexing the thigh toward a right angle, and abducting slightly to disengage the head. The thigh is then strongly rotated inward, adducted, and then the whole limb brought down straight. This maneuver tightens the Y-ligament and obturator muscles by inward rotation while the thigh is flexed; then as the thigh is extended, while inward rotation is maintained, the ligament and muscles act as a fulcrum, and the head is lifted up over the lower rim of the acetabu-

lum. To facilitate this last step, Bigelow advised passing a towel around the upper part of the thigh and making traction outward and forward. He also placed the patient in some cases in a sitting position with a log or post between the upper part of the thighs, and by making adduction pried the head outward, and with outward rotation moved it upward to its socket. From a theoretical standpoint, it would seem that this outward rotation is the important movement to cause the head to ride over the acetabular brim.

Stimson, in his cases, effected reduction by increasing the flexion and rotation, making traction in the direction of the long axis of the thigh, and then carrying the whole leg down straight and rotating inward.

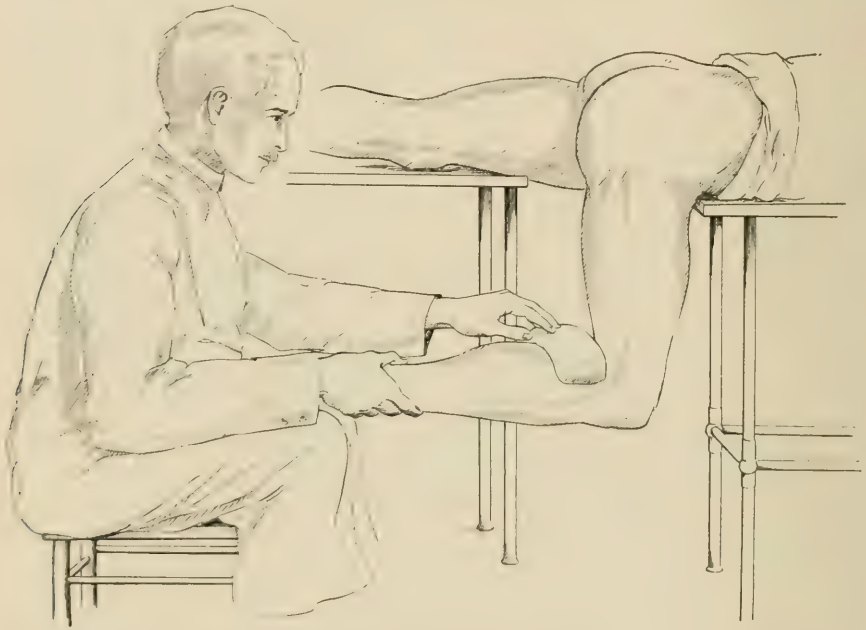


FIG. 481.—REDUCTION OF POSTERIOR DISLOCATION OF HIP BY GRAVITY. (*Method of Stimson.*)

A sand-bag may be placed on the back of the leg to add to the gravity traction. (*J. P. W.*)

Kocher flexed the thigh to a right angle while preserving the abduction and outward rotation which is usually present. Traction in the direction of the long axis of the femur is then made to bring the head near to the socket. While the posterior part of the capsule and the Y-ligament are thus held tense, outward rotation is made to bring the head upward and backward into the socket. Stimson cites a case in which Kocher reduced a dislocation of four weeks' standing by applying continuous traction in the direction of the long axis of the thigh (partial flexion, abduction and outward rotation), combined with continuous outward and forward traction. On the fourth day it was found that reduction had quietly taken place.

Reduction of *perineal* dislocations is accomplished by flexion and traction in the direction of the long axis of the femur. This maneuver converts the dislocation into the obturator form, and when continued, it effects reduction because of the great relaxation of the ligaments. The tearing of the ligaments in this dislocation is so great that, when the muscles are relaxed by anesthesia, the head can simply be lifted into the socket.

Dislocations downward upon the ischium are those in which the head rests between the positions of dislocation upon the ilium and dislocation in the obturator foramen. In attempting its correction it may be converted into one or the other of these forms. Reduction has usually been accomplished by traction in the direction of the long axis of the flexed thigh with pressure upward and forward upon the head.

Dislocations forward are characterized by an escape of the head below the Y-ligament. They may sometimes be forward displacements of downward dislocations. This is the dislocation in which the great vessels of the groin have sometimes been ruptured. Extension of the thigh is dangerous because of the possibility of stretching the vessels over the head of the femur. Bigelow's method of reduction as applied by Kocher is as follows: Traction is made in the direction of the long axis of the femur as it lies. This makes the posterior part of the capsule tense and draws the head outward. An assistant then makes outward pressure upon the head of the femur to prevent its return inward while flexion of the thigh is made. Flexion relaxes the Y-ligament; but it should not be carried to a right angle lest it make too great strain upon the posterior part of the capsule. Then the thigh is rotated inward to carry the head out to the socket. Often traction and outward pressure upon the head suffice to effect reduction.

If the dislocation was originally of the downward variety, flexion of the thigh and outward traction will return the head to its original dislocation. In extreme inward dislocations, in which the head lies in the pelvis or above the pubes, outward traction must be combined with traction in the long axis.

Dislocations upward, in the direction of the anterior-inferior spineof the ilium, are rare. Those cases which have been observed have been reduced by traction upon the slightly flexed thigh applied in the direction of its long axis. Downward and backward pressure upon the head or inward rotation have also been required.

Dislocations through the floor of the acetabulum must needs be complicated by fracture. Reduction should be made by traction in the long axis of the thigh combined with outward traction upon the upper end of the bone. Following this pressure should be made against the inner side of the pelvis to press back displaced bony fragments. This may be done by means of a blunt instrument in the rectum. Continuous traction should be applied to the thigh as in fracture of the neck of the femur, and maintained for a month after reduction. This pressure in the rectum should be made very carefully and gently. If there is a sharp spicule of bone which might wound the rectum or if the pressure necessary to replace a fragment has to be so great that damage to the rectal wall might be caused, all such pressure should be omitted. It is much safer to make an incision midway between the anus and tuberosity of the ischium, pass an instrument or a gloved finger into the ischiorectal space, and press back the fragments, than to take any chances of injuring the wall of the rectum.

The **after-treatment of uncomplicated dislocations** after reduction should consist in rest in bed with a hip spica and a long side splint for two weeks. After that the patient may gradually be given more and more liberty until by the end of the third week he is allowed to walk. In dislocations in which the elements of the joint have been so widely separated as to necessitate much tearing of the ligaments confinement should be extended to a month.

Complications of dislocations of the hip are of as great frequency as with other dislocations. Rupture and lacerations of *muscles* and *ligaments* heal under the quiet and immobilization called for by the dislocation. Injury of the *femoral vessels* occurring in anterior dislocations call for the treatment already laid down (see Injuries to Blood-vessels).

Fracture of the neck of the femur occurs at the time of dislocation or as a result of efforts at reduction. Manipulation under anesthesia should first be attempted to put back the head into the socket. The thigh itself should be but little moved in order to retain unbroken as much periosteal connection as possible between the two fragments. If reduction is accomplished, the treatment then becomes that of fracture of the neck. If reduction is not accomplished by manipulation the surgeon who can command aseptic operative environment should expose the head by one of the incisions described for gaining access to the joint, replace the head and fix it firmly to the neck by means of absorbable sutures passed through holes drilled in the fragments or held by ligamentum teres on one side and bone or periosteal tissue upon the other. Or a peg of bone may be driven from without inward through the base of the trochanter (see Fractures of Neck of Femur, page 583).

In lieu of these expedients there remain several courses which may be pursued. Union may be allowed to take place with the leg in the best position possible. The limb may be put in such position as will give the most accurate bony union possible, after which attempts at reduction may be made or the treatment of old unreduced dislocation applied. Excision of the head has been done, and the stump of the neck placed in the socket. When this operation is performed a shortening of the capsular ligament should also be done. Such an operation is rarely justified, because if the surgeon is competent to open the joint he is competent to unite the fracture.

Fractures of the shaft of the femur are less difficult to manage than fractures of the neck. The longer the upper fragment, the easier the reduction. Rotation is the only manipulation which is excluded. But most dislocations can be reduced by traction and pressure upon the head. McBurney's hook or lion jaw forceps should be of service to control the upper fragment through a wound made for the purpose. Union of the fracture has been secured in some cases and then attempts at reduction made. The best treatment consists in careful attempts by pressure upon the head and manipulation. These failing, the head should be exposed by incision and reduced at once, and then the treatment of the fracture proceeded with.

Habitual dislocations occur as a result of elongation of the capsular ligament, usually following traumatic dislocations which have not been given sufficient time to heal. While not common, they are sufficiently frequent to teach the necessity of good attention to the treatment of dislocations after reduction. The most reasonable thing to do for these cases is to expose the capsule and tighten it. This should be done at the place where the head escapes; and it may also be done at the opposite side of the joint (see Habitual Dislocation, page 632).

Old unreduced dislocations may be the name applied to dislocations of more than two months' standing, although older dislocations than this have been reduced and younger ones have failed of reduction. The joint changes are similar to those described in connection with the shoulder but the danger to vessels is less. The head makes a new socket, becomes surrounded by fibrous deposit, and in the course of time the acetabulum grows shallow and looses its synovial lining. When a dislocation fails of reduction by manipulation, the sooner reduction by means of operation is attempted the more easy will it be and the better the result. It is true that people go through life with unreduced dislocations, but it is as much for want of proper treatment as that they do the same with club feet or viciously united fractures.

In deciding upon *arthrotomy*, the same general rules apply as apply to the shoulder. If the patient is past middle life the question of pain may determine operation; if the limb is comfortable and fairly useful, arthrotomy is not called for.

Arthrotomy and open reduction are indicated in the young and healthy.

The common backward dislocation is best reached by a posterior incision. Forward dislocations are exposed by an anterior incision (see Joints, pages 748 and 783). For posterior dislocations Rydygier preferred a curved incision with its convexity downward passing 6.5 cm. (2½ inches) below the tip of the great trochanter, the anterior end running toward the anterior-superior spine of the ilium, and the posterior end toward the posterior-superior spine of the ilium. The trochanter is sawed through very obliquely and with its attached muscles reflected upward. This gives a free exposure of the joint. The obliquity of the osteotomy permits the trochanter to be replaced successfully. Whatever method of approach is used the head and neck are exposed and freed from attached structures. Muscles must be cut loose from the neck. The acetabulum is prepared for the reception of the head by removing adherent capsule and connective tissue. In recent cases it will be found free. Often exostoses or detached cartilage must be removed or corrected. Contracted muscles must be detached from the trochanter, if the latter has not been divided, until reduction can be effected. If the acetabulum has become shallow, it must be deepened with curet and chisel. After reduction, the capsule and muscles should be sewed in place, relaxed ligaments being shortened, and the limb immobilized in such position as tends to give relaxation of sutured parts and to hold the head in place. Usually this is best accomplished by abduction combined with traction in the long axis. The operation of arthrotomy for dislocation demands asepsis, and the surgeon who can not command it should not take the risk. The operation should not be accompanied by great force at reduction as tissues are lacerated and devitalized thereby. Reduction failing, excision of the head remains as the next recourse.

Excision of the head is called for also in the old or in persons not strong enough to be subjected to operative reduction. It is done especially to relieve pain due to pressure of the head, but it cannot often be expected to improve function.

Osteotomy of the neck or below the trochanter may be done (see Osteotomy, of Femur, page 714) to secure better position when operative reduction is contraindicated. It offers much in such cases. The same result has been reached by accidental fractures caused by attempt at reduction, after the fracture, the limb being put up in corrected position, the dislocation not being reduced.

In determining these operations the surgeon must consider the prospects of function without operation, and having begun an operation for reduction he should be ready to desist or change his plans to osteotomy when the conditions so demand. Many useful limbs have been secured by the surgeon being satisfied with the abnormal position of the head, and securing a good position of the leg by osteotomy.

Congenital dislocations (see page 613).

DISLOCATIONS OF THE KNEE

In the event of rupture or occlusion of the vessels, reduction should be accomplished, and then the injury of the vessels dealt with according to the principles already given (see Gangrene, Wounds of Vessels, and Fractures of the Lower End of the Femur). After reduction of these dislocations the joint should be immobilized for three weeks in very slight flexion.

Forward dislocations of the tibia upon the femur are best reduced by traction and backward pressure upon the front of the tibia. It is important that extension of the joint shall be carried no further than when found for

fear of stretching the popliteal vessels to the point of rupture. If overextension is present the joint should be slightly flexed. In making traction and in holding the limb, care should be taken not to press upon the vessels as they lie stretched in the popliteal space. The lower end of the thigh should be rested upon a sand-bag; counterextension should be made at the perineum or shoulders; traction upon the leg should be steadily increased, as backward pressure upon the front of the tibia is made. Under no circumstances should traction be made when the thigh can become more extended. If the surgeon has reason to be greatly concerned for the vessels, to be on the safe side, the joint may be flexed more or less to relax them while efforts at reduction are made.

Backward dislocations are reduced usually without difficulty by traction and anteroposterior pressure. The knee should be flexed to relax the posterior structures and the hip to relax the quadriceps extensors. Any further extension of the joint should be guarded against. Flexion should be made as soon as possible.

Lateral dislocations are either inward or outward, and are reduced easily by traction in the direction of the long axis of the limb and by lateral pressure. The tearing of the lateral ligaments which accompanies this injury leaves a tendency to weak joint or to genu valgum or genu varum. This must be prevented by rather prolonged immobilization, best effected by a splint having a hinge which prevents lateral motion but allows flexion and extension. As a result of lateral dislocation, after removal of the splints, one or both ligaments may remain weak, despite massage and exercise. This can be corrected by operative exposure of the elongated ligament, and by shortening it according to the methods described for the operative treatment of recurrent dislocations (page 612).

Rotary dislocations are treated by revising the movement which caused the lesion.

Congenital dislocations have usually been represented in the form of overextension. The treatment found effective has been gradual flexion, with a brace to prevent extension beyond the normal. As the child grows, the parts, if kept in normal bounds, become corrected.

DISLOCATIONS OF THE PATELLA

Lateral dislocations are reduced by extending the leg, flexing the thigh to relax the quadriceps, and pressing the displaced bone into place. If this does not succeed a hook may be put into the patella to help draw it in position. The quadriceps muscles may be further relaxed by anesthesia and by drawing them downward upon the front of the thigh.

Rotary dislocations are reduced in the same manner as the above, pressure upon the edges of the bone and manipulation being required.

When these measures fail, *open operation* is called for; but before opening the joint the bone should be exposed and further efforts made to reduce it by means of hooks or heavy bone forceps. (For the general technic of such operations, see Operative Treatment of Fractures of the Patella, page 598.)

Habitual dislocations occur as a result of undue relaxation of the lateral reflections of the patellar fascia. Several methods of treatment are available. One is the wearing of a leather cap strapped to the front of the knee, which prevents displacement. Another is the operative exposure and shortening of the elongated fascia. The difficulty may also be met by transplanting the tibial insertion of the ligamentum patellæ inward or outward as the case may require. In shortening the fascia, it may simply be thrown into a single fold by means of a few sutures, or the fascia may be divided and sutured in an overlapping position. (For Osteoplastic Treatment, see page 787.)

DISLOCATIONS OF THE FIBULA

These dislocations may occur at either the upper or lower end. Reduction is effected by pressure and manipulation. If not accomplished, open operation is called for.

DISLOCATIONS OF THE ANKLE

Backward dislocation is corrected by making traction or pressure forward upon the foot and backward against the lower end of the tibia. It is important that a splint should be applied which continues to make forward pressure against the heel in order to prevent recurrence. Immobilization should be maintained for three weeks.

Forward dislocation is reduced by backward pressure on the foot combined with traction.

Lateral dislocations are corrected by traction, lateral pressure and manipulation.

DISLOCATIONS OF THE TARSAL BONES

Dislocations of the astragalus may be in any direction. Reduction should be attempted under general anesthesia with the knee flexed to relax the sural muscles. Traction should be made upon the foot and pressure applied to the displaced bone. If manipulation fails, arthrotomy is called for. Upon exposing the bone the obstruction usually will be discovered. If the operation is aseptically done, a good result should be expected after reduction, nor is it necessary to excise the bone if it is found broken.

Old unreduced dislocations are to be treated by exposure of the bone. If reduction can not be made because of old adhesions and changes in the contour of the structures, removal of the astragalus gives a satisfactory result.

Dislocations of other tarsal bones are to be reduced by traction upon the bones lying anteriorly, and by corrective pressure. These failing, operative exposure of the bone and reduction by the aid of sight are called for.

DISLOCATIONS OF THE METATARSAL BONES AND PHALANGES

Many varieties of these dislocations occur, taking place in any direction or involving one or several bones.

Reduction is accomplished by traction upon the toes and corrective pressure.

In some cases of *dislocation of the great toe* reduction is prevented by the tendons falling between the bone ends. It will sometimes be found advisable to cut the tendon of the long extensor of the toe, make strong flexion and then traction. When this is done the tendons of the short flexor, adductor, abductor and the long flexor, which press the capsule between the bones, are disengaged and reduction is accomplished. The cut tendon is then sutured and the wound closed.

DISEASES OF JOINTS

TRAUMATISM OF JOINTS

Traumatism, due to contusion, sprain, rupture of ligaments, or dislocation of cartilage, may set up a synovitis, depending more or less upon other constitutional irritative conditions, the treatment of which is discussed under Acute Synovitis.

SPRAINS

The treatment of sprain involves two conditions, the wounds of the ligaments and the traumatic synovitis. As in all wounds, rest is essential. Unfortunately the torn parts are often held asunder by blood and exudate. Therefore, combined with rest, the surgeon must apply measures to hasten absorption. This is best accomplished by the application of heat and an immobilizing bandage. The bandage must not be tight enough to interfere with circulation. The immobilization need not be absolute. If the joint is seen soon after the injury, and swelling is still going on, the exudation may be stopped by cold applications for a few minutes, or by a tight flannel bandage.

To cause the absorption of the products of traumatism, hot applications are better than massage, because they may be used without undue moving of the tissues. The progress of the swelling having been stopped by cold or pressure, a good plan is to envelop the joint in a steaming hot woolen compress, covered by some impervious material to retain the heat. Such hot applications may be kept on for an hour at a time with intervals of three or four hours. After removing the hot applications, the parts should receive a cold douche, be dried and immobilized with a simple bandage. Instead of hot compresses, the joint may be plunged in water as warm as the skin will tolerate, or the dry air oven may be used. When the swelling and ecchymosis have gone, gentle compression with a bandage and immobilization are called for. The joint should always be held in such position as to relax the torn ligaments. Thus if the sprain were produced by abduction, it should be held in a position toward adduction.

Old sprains, in which the joint is still painful and weak, should be studied to discover the cause of the trouble. No routine treatment is applicable to all. If there is still swelling, its subsidence should be expedited by hot applications followed by cold, or by the use of massage, or vibratory stimulation. If there is undue relaxation of the injured ligament, the joint should be immobilized in an overcorrected position, relaxing the injured parts. A plaster-of-Paris or other splint may be left on for two weeks, and then daily or twice daily massage, applied. When pain is due to synovitis, the proper treatment for that condition should be applied.

Sprains of the Ankle.—These sprains are treated upon the general principles above described. Stop the hemorrhage and exudate during the first hour or two after the accident by cold or compression; rest the parts with the injured ligaments relaxed; facilitate absorption by stimulating circulation during the next day or two; immobilize and support until the wounded ligament is repaired—these are the steps of treatment. They are best

carried out by applying an ice-bag or a snug flannel bandage for an hour and then proceeding as follows: The foot and ankle are immersed in a vessel of hot water for half an hour, and the foot taken out and held under cold running water for half a minute. It is then dried and a flannel bandage applied from the toes to above the ankle. The patient sits with the foot resting on a cushion, and the leg horizontal. The heat and cold are repeated every four hours, and the rest between entailed. Care should be taken that the ankle-joint is not moved and that the sprain position is over-corrected. After one, two or more days, when the swelling and pain have gone, a dressing to give even pressure and immobilization should be applied. For this purpose may be used a flannel bandage, put on snugly and with each turn covering at least two-thirds of the previous turn. If it is necessary for the patient to be about, over this may be drawn a high shoe; and so long as the ankle is not bent the patient may be allowed to walk. More rapid healing will be secured if walking is not practised until it can be done without pain or discomfort.

One of the most effective means for securing pressure and immobilization is by the use of strips of moleskin or adhesive plaster. This may be cut in strips for ease of handling, one yard long and 2 cm. (¾ inch) wide. The foot is placed in easy position, flexed at a right angle. The strips are heated over an alcohol lamp, and put on as a bandage, beginning just back of the toes and continuing as a figure-of-eight bandage until the foot and ankle are covered (see Bandages of the Foot, Vol. III). Each turn covers half of the preceding turn. When the end of a strip is reached, another continues from that point on.

Before beginning, a longitudinal strip should be laid along in front and behind each malleolus to strengthen the dressing. The patient then may draw on a stocking and shoe, and walk.

In the case of bad sprains with much tearing of the lateral ligaments or with much synovitis, more perfect rest may be secured with a plaster-of-Paris bandage, and abstinence from use of the foot.

Sprains of the Knee.—The condition usually requiring treatment here is that of synovitis. Rupture of ligaments demands immobilization for at least three weeks. Hemarthrosis is best treated by making lateral openings and washing out the clots. If the joint is much distended with inflammatory fluid, aspiration will hasten healing and save the ligaments from becoming unduly relaxed.

Sprains of the Sacro-iliac Joint.—This joint is susceptible of both acute sprains and sprains with chronic synovial irritation. The treatment of the first variety should be by rest in bed in the horizontal position. Severe cases should have the benefit of a tight adhesive strip embracing the whole pelvis, or a plaster-of-Paris casing, applied snugly around the hips, pelvis and loins. A moulded leather girdle is of service. In old or chronic cases, counterirritation is of value. This should be applied opposite the joint by means of iodin, the actual cautery or some other agent (see Synovitis).

Sprains of Vertebræ.—These injuries often belong to the subluxations already discussed (see Dislocations of Vertebræ, page 620). So long as pain and tenderness are present rest should be entailed. A plaster-of-Paris girdle may be necessary to accomplish this. Mechanical stimulation by vibratory massage is of service to hasten the absorption of exudate.

Sprain of the Temporomaxillary Joint.—In this lesion the synovitis is the condition requiring treatment. Rest of the jaw is secured by bandaging the jaws together and the use of soft foods. Counterirritation in the form of heat, iodin or blisters is of service.

Sprains of Other Joints.—It is often difficult to differentiate which is the more important lesion, the sprain or the traumatic synovitis. In the *hip*, the condition usually requiring treatment is the synovitis. The *wrist* is frequently sprained, and immobilization by means of splints is necessary for the tenosynovitis as well as for the injured ligaments. The *elbow* is often sprained, and treatment by immobilization is necessary; but before it is begun the surgeon should be sure that the injury is nothing more than a sprain. Sprain of the *shoulder* produces often a troublesome synovitis, which requires rest and support of the elbow to relax the ligaments.

DISLOCATION OF CARTILAGES OF JOINTS

These conditions are the results of traumatisms. In some joints cartilages are broken loose at the time that a dislocation occurs. In such cases the displaced cartilage is usually replaced by the reduction of the grosser dislocation. If it remains displaced, and can not be returned by manipulation, the most satisfactory result is secured by cutting down upon the joint and replacing it by sutures or if this can not be done removing it.

Dislocation of the Semilunar Cartilage of the Knee-joint.—This is the most common of all of these derangements; usually the internal cartilage is affected; it occurs as the result of catching a floating body against the cartilage, or strain associated with rotation of the joint. If the protruding cartilage can be pressed back, recurrence is very apt to take place. Reduction can best be accomplished by flexing the knee, and then making rotary motion with traction while pressure is made upon the cartilage. The union of the cartilage to the tibia in its normal position is the next desideratum. It should be thought of as a fracture. Without immobilization, it will not heal. In recent injuries there is some effusion of blood into the joint and the patient should be kept quiet.

Several plans of treatment are of service. The limb from the lower part of the leg to the upper part of the thigh may be put up in a plaster-of-Paris or other light splint, fixing the knee in a slightly flexed position. With this the patient may go about with crutches. At least four weeks should be given for the union to take place. Shaffer (Annals of Surgery, vol. 28, 1898) applied with success to this condition a brace, which is so constructed as to prevent all motions of the joint except hinge-like flexion and extension. The apparatus stops extension before it becomes complete. A pad makes pressure over the cartilage. Patients who have suffered incapacity from repeated recurrences of dislocation have put on this apparatus and had complete use of the limb immediately. It is worn for several months to insure union of the cartilage.

A simple treatment consists in placing a pad of folded gauze, wool or cotton cloth or leather against the region of the cartilage. This pad should be about 9 cm. (3½ inches) long, and 5 cm. (2 inches) wide. It should be placed transversely, and be held with adhesive strips. Over the region of the knee should be applied a flannel bandage.

Operation had best not be considered unless recurrences take place. The operative treatment consists in cutting down upon the loose cartilage, exposing it and sewing it in place by a few stitches to the capsular ligament. The joint is closed and immobilized for four weeks, after which it is gradually used. The results of this operation are good. When the cartilage is found bent and irreplacable it should be removed. Removal of the cartilage is the quickest method of operative treatment, but has the disadvantage of sacrificing the cartilage which plays a rôle in the proper functioning of the joint. Operation should not be done in the case of a recent dislocation, but

several days of rest should be given for the subsidence of the traumatic reaction. Variable results have been secured. Many surgeons remove the cartilage in all cases and report good results.

Fractured cartilages are treated in the same manner as dislocated cartilages.

INFLAMED PATELLAR PAD

The fatty fringes, covered with synovial membrane, hanging into the knee-joint from the patellar pad, become pinched and traumatized between the patella and the femur. If attention to the resulting synovitis does not give relief, the most satisfactory treatment consists in opening the joint and removing the offending tabs. This operation is done through incisions on either side of the patella.

RELAXED CRUCIAL LIGAMENT

The anterior ligament is the one which requires attention. The joint is opened (see Opening Knee-joint, page 752) and the ligament exposed. A hole is drilled through the external condyle of the femur, close to the insertion of the ligament. A loop of kangaroo tendon or heavy chromicized catgut is passed around the ligament and the ligament is drawn into the hole by means of the loop. The two outer ends of the suture material are passed through the fascia under the skin with a needle and tied. The knee should be immobilized on a splint with a slight degree of flexion.

RUPTURE OF THE CRUCIAL LIGAMENTS

Sprains and traumatic synovitis often mean rupture of the crucial ligaments. A strong knee may be secured by opening the joint and suturing the ruptured ligament. Operation is called for only if the injury has left the joint weak or painful. Operation has been done with good result in cases in which three months have elapsed between the injury and the operation. One or both ligaments may be found ruptured and requiring suture. Chromic catgut should be used, and the joint immobilized for at least three weeks. (For gaining access to the joint see Opening Knee-joint, pages 749 and 752.)

Often this injury is associated with tearing out of the spine of the tibia. This may be treated by passing a kangaroo tendon through the ligament, inserting the two ends in holes in the head of the tibia, and driving bone pegs in the holes to hold them there.

LOOSE BODIES IN JOINTS

If a loose body is of sufficient size it may be identified from the outside. In such a case it should be pierced by a needle, to hold it from slipping away, and cut down upon and removed. Smaller bodies which require removal must be exposed by arthrotomy. When many are present they may be washed out with saline solution.

OTHER INTERNAL DERANGEMENTS OF THE KNEE

When there is doubt as to the nature of the internal derangement the joint is best opened through the split patella (page 753). Loose semilunar cartilages may be sutured in place through this opening, stretched or ruptured crucial ligaments may be repaired, and a general view of the interior of the joint secured.

Intra-articular fracture of the lower end of the femur, which consists usually of a fragment broken from the internal condyle, is best discovered

through the split patellar incision. A hole may be drilled through the condyle and the fragment held by a suture or bone peg.

Fracture of the spine of the tibia, carrying with it the crucial ligament, may be treated by immobilizing the joint in slight flexion, and waiting for the inevitable weakness which must follow. The well-equipped surgeon will get a better result by opening the joint by bisecting the patella (page 753), drilling a hole on either side of the detached spine, transfixing the ligament with a heavy kangaroo tendon, and fixing the two ends of the kangaroo tendon in the holes by means of bone pegs (Fig. 482). This operation is applicable to one or both spines.

FIG. 482.—RUPTURE OF CRUCIAL LIGAMENT.

Kangaroo tendon passed through ligament, and the ends of the tendon fixed in holes in the head of the tibia by means of bone pegs.

WOUNDS OF JOINTS

Wounds of joints are of importance on account of the dangers inherent in infection. Infection, once developed in a joint, is prone to spread to all parts of the synovial membrane, which is poorly resistant against infection and richly absorbent of infective products. The prevention of infection is of the first importance. Infection having taken place, its spread is inhibited by *immobilization* of the joint. If the infection produces exudates which distend the joint, then their removal is called for.

Aseptic wounds are usually those made by the surgeon. In closing them the parts should be sutured in their normal relations. In closing the synovial membrane, the suture should be of fine absorbable material, and preferably not passed through the synovial lining but only into the tissue external to it.

Punctured wounds, the result of accident, usually carry into the joint some infective matter. It is possible for the wounding object to be wiped so free of dirt, as it passes through clothing and tissues, that little or no infection reaches the joint. This is sometimes the case with bullets and sharp-pointed instruments. In treating these wounds it is not imperative that the surgeon should determine whether the joint has been penetrated. This information can not materially alter the treatment. The escape of some synovial fluid with its shiny, viscid, mucoid appearance, is often the only guide. By no means should a probe be inserted into a wound to determine whether the joint has been penetrated; probing a fresh wound of a joint is one of the sins not committed by a surgeon. The immediate diagnosis is not of so great importance that it is justifiable to insert an instrument, which may carry on into the joint infective material which was lodged in the wound tract external to the joint, or may penetrate a synovial membrane which had not been opened. If this book prevents one person from committing this blunder it has fulfilled a mission.

In most of these wounds the surgeon cannot be sure whether infection has taken place or not. Usually, if the wound is inflicted by a pointed instrument, no spreading synovitis will occur if the wound is treated promptly with iodin, covered with a dressing, and the joint immobilized. If the surgeon

has good reason to believe that infection has occurred, as in the case of a penetrating wound made with an instrument or through materials known to be soiled with virulent organisms, then the joint should at once be treated as though infection had already developed. Such a wound should be retracted and dried throughout its whole extent and then thoroughly treated with tincture of iodin. Any mild chlorin-liberating antiseptic or phenol may be used. This is for the sterilization of the wound of entrance. The joint cavity itself should be sterilized by injecting 10 or 20 c.c. (150 or 300 minims) of chloraminated oil or a mild hypochlorite solution. The wound may then be closed except for a rubber drain carried to the joint but not in it. If these substances are not at hand, and it appears that infective material has been spread away from the wound of entrance in the joint cavity, it should be washed out with saline solution or water. A copious protective dressing should be applied and traction instituted. At once upon the appearance of symptoms of infection, usually after thirty-six or forty-eight hours, the joint should be incised, and again injected with mild antiseptic solution. If this treatment repeated does not control the infection, the joint should be provided with openings in front and behind, irrigated through-and-through with a large amount of chlorin solution, and tubes placed to drain it. The joint should be kept immobilized with traction.

Infected lacerated and **incised wounds** should be treated the same as the above. The synovial surface should be traumatized as little as possible. It should be assumed that all accidental non-operative wounds are infected. They should be cleansed of all possible foreign material; but pains should be taken not to carry any infection into the joint. The wound should be retracted so that all of the parts may be reached and dried. Iodin or chlorin solution should then be applied to the wound (see Treatment of Wounds, page 237). The surrounding skin should be asepticized and the wound closed by sutures. The iodin should not be applied to the synovial surfaces. Over all should be placed a copious dressing and the joint immobilized with a splint. Larger joints should be relieved of pressure by traction. The dressing should be renewed at the end of one or two days. If the wound has been much soiled and is left open, it should be sprayed daily with 2 per cent. iodin in alcohol or chlorin solution. The first suggestion of a spreading synovitis, appearing after thirty-six hours, should be met by freely opening and washing out the joint with a mild antiseptic or salt solution. In the absence of this treatment, a free counter-opening should be made in the most dependent part of the joint, the wound of accident should be reopened and copious irrigation with sterile water practised, the fluid being introduced at the surgical wound and allowed to run out of the wound of accident. The irrigation should be made with sufficient force to distend and reach all parts of the joint. Drainage tubes should be inserted into the joint through each wound.

If the infective synovitis is not held in abeyance by this treatment, continuous irrigation may be inaugurated or irrigation several times daily practised. After a few days, it will usually be observed that the infection is subsiding. Drainage may be discontinued when the infection is gone. As the symptoms subside, dressings should be done less frequently.

In the event of synovitis which is not controlled by these measures, the joint must be irrigated constantly with antiseptic solution. For this purpose solutions of iodin or chlorin are most effective. The irrigations should fill the joint. If the infection is not controlled by these measures, the joint should be opened more freely in order to secure immediate removal of infect-

ive material from the joint recesses. For this purpose long lateral incisions should be made to give access to every part. Through these the irrigation should be made to reach the remotest parts of the joint. It is not sufficient that fluid should pass through the joint; the requirement is that every part shall be reached.

In intractable infections of the *knee-joint*, if the above treatment fails, rather than perform amputation or sacrifice the patient to septicemia, before these have become necessary, the surgeon should lay open widely the whole interior of the joint by such an operation as is done for erasion of the joint or synovectomy. Usually a curved incision, its convexity downward, passing from one side of the joint, below the patella and ending at the opposite side of the joint, is made. The flap, containing the patella, is turned up, and by flexing the knee, the whole interior of the joint is exposed. Having exposed all of the synovial membrane, every bit of it should be treated directly with phenol followed by alcohol. Ether or iodin may be used instead. The joint may be put up with multiple-tube drains, or large openings may be made through which gauze is led out after it has been applied to all of the joint-lining. The patellar flap may be replaced and sewed in the middle or the suturing may be deferred. This treatment may be expected to give soft ankylosis, and to save the life of the patient if toxemia is not too far advanced.

Good results in wounds of joints may be secured by the following steps: (1) The wound should be sterilized with tincture of iodin without touching the synovial lining; (2) pieces of bone, lacerated tissue and foreign matter should be removed; (3) the opening into the joint should be closed with sutures, uniting capsule, ligaments and skin without drainage; (4) a needle should be passed into the joint and the joint injected with 10 or 20 c.c. (150 or 300 minims) of chlorin solution or 2 per cent. formaldehyde in glycerin solution; and (5) the joint should be immobilized and relieved of pressure by traction of 15 or 25 pounds. Following this a slight rise of temperature is present for a few days. The presence of distention of the joint calls for aspiration and repetition of the injection. By this method of treatment a large proportion of infections of joints may be conducted to healing without ankylosis. If the wound is very large or if the sutures do not hold, and the injected fluid cannot be retained but flows out of the joint, it must be treated as an open wound with drainage. In the stead of these, any antiseptic having an equal potency may be employed.

Gunshot wounds, bullet wounds or wounds caused by exploding shells, require the same general treatment as that already given. The wound should be covered with sterile material until the skin and wound can be treated. If it is a small punctured wound made by a bullet, the presence of the bullet should not receive as much consideration as the question of synovitis. Bullets from high-velocity firearms produce wounds which are surprisingly free from infection if the wound is protected at once with a sterile covering to prevent secondary infection. As soon as possible chlorin or iodin should be applied to the wound. It should then be covered with a sterile protective dressing. If these are not at hand, the surrounding skin should be cleansed as for an operation, and, if there are no conditions requiring especial attention, a copious wet antiseptic dressing may be applied. In any case the joint should be immobilized and the patient kept at rest. Unless the objects or the skin through which the bullet passed were grossly infected, no spreading synovitis may be expected, and the surgeon may await developments. The smaller, the swifter, and the harder the bullet the less the danger.

The lodging of the bullet in or near the joint requires no special treatment unless it is a source of trouble. It is highly undesirable to attempt to remove a bullet from a joint during the first few days when it is probable that no infection will develop. Only if the bullet has penetrated dirty skin or clothing or is making trouble, is its removal to be attempted. This is best not done until it has been located by the *x*-ray or can be felt through the skin. To open a joint and seek for a bullet before locating it, is apt to be a disappointing operation. The development of spreading synovitis requires the same treatment as that following other infected wounds. The more clothing the bullet penetrates and the less clean the patient's skin the greater is the danger of infection. It is observed in war that in summer when the men have bathed frequently and have worn thin clothes there have been the fewest infections.

Tearing wounds, made by large or soft bullets or by shells, require the treatment of the wounds of the soft tissues and of the bone. Completely detached pieces of bone should be removed, as well as foreign material; but on the whole the most conservative surgery should be employed. It is surprising to see how well these wounds do when treated by conservative methods. Iodin or chlorin to the wound, an occlusive dressing of sterile gauze, and immobilization are three potent factors for good in these cases. The wound should be treated the same as a compound fracture. If antiseptic is not at hand the skin should be scrupulously cleansed, drainage provided, a copious sterile dressing applied, and the part immobilized. It should do well. Secondary sutures may be applied after three or four days when the danger of sepsis is passed (see Bullet Wounds, page 222).

Wounds of joints with compound fracture are most serious, and require the treatment given for infected wounds. Pieces of detached bone should be removed, displacement corrected, and then the joint treatment undertaken. The outer wound should be disinfected with chlorin or iodin down to the synovial membrane. The wound should be sutured tightly without drainage, unless it is extensive and ragged, and then a small rubber drain may be carried down to but not through the synovial membrane. The joint should be immobilized and pressure relieved by traction with a weight of 15 to 30 pounds or sufficient to meet the needs of the fracture. Upon the appearance of infection, the knee-joint should be opened by the anterior U-incision. Resection should be done if sepsis is not promptly controlled (see above; also Compound Fractures, page 518).

SYNOVITIS AND ARTHRITIS

Traumatic synovitis requires immobilization of the joint as the most essential part of the treatment. In the shoulder this may be secured by a bandage fixing the arm to the thorax and supporting the elbow to take the weight of the arm from the ligaments of the shoulder joint. In the hip, a long side splint, from the axilla to the ankle is most satisfactory. A simple posterior splint with a small pad to give slight flexion is used at the knee. The joint should be relieved also of pressure and weight bearing as much as possible.

In addition to immobilization, healing may be hastened by increasing the blood-supply by means of hot applications. These may be in the form of woolen cloths wrung out in hot water or the dry heat of the oven used for that purpose. A snug bandage evenly applied also serves to hasten the absorption of exudate.

After the acute stage has passed, the joint should be kept at rest, and resolution may be expected to take place. Under the above treatment

recovery should be complete in from two to eight weeks. After the fluid has been absorbed immobilization should be continued until the pain and soreness, due to the thickening and inflammation of the synovial membrane, have subsided. Active artificial hyperemia will hasten this; or massage, heat, alternating heat and cold, or counterirritation may be employed.

The immobilization should not be continued beyond the healing of the inflammation, because of the atrophy and soreness which often are caused by immobilizing a well joint.

Chronic synovitis is due to so many different causes that treatment can not properly be inaugurated unless the special etiological factor is recognized. Immobilization is the one measure called for in all cases. In addition to this, other measures are indicated.

If the disease is due to repeated attacks of acute synovitis, counter-irritation is of service. This may be secured by means of several coats of tincture of iodin, applied twice a week. A blister applied opposite the sore place or on either side of the joint is effective. Hot applications for half an hour, followed by a cold douche for a minute, twice daily is most useful. Blistering the skin with the actual cautery is also effective.

When the mechanical irritation is within the joint, such as is caused by hypertrophied fringes or loose bodies, the treatment consists in removing the cause. The same may be said of the disease when it is due to auto-intoxication which causes irritation of serous membranes: the general hygiene of the patient should be looked to.

Atrophic synovitis, consequent upon muscular atrophy and relaxation of the ligaments, these often following acute synovitis or prolonged immobilization, is the one form of synovitis which does not require immobilization. Massage is of much value. Passive and active motion, electricity, mechanical vibration, hot and cold douching and other stimulative measures are called for.

Exudative synovitis, giving rise to distention of the joint with serum or pus, may be present in either acute or chronic inflammation. Usually the exudation of fluid is slight in cases of synovitis; but in very acute cases, in persons with deficient resistance, and in cases in which treatment was not promptly begun, the exudate may be so excessive as to distend the joint. When such distention has reached a certain point the pressure becomes so great that absorption is hindered. In such cases the joint should be evacuated. Thin fluid is removed through an aspirating needle, thick fluid by means of a trochar and canula or by incision.

A tensely distended joint should not be left with the internal pressure unrelieved, because of the damage which is being done to the synovial membrane and the ligaments. The operation should be conducted with every care to prevent carrying infection into the joint (see Preparation for Operation, page 177). Local anesthesia or no anesthesia may be used. If the fluid is serum, following its withdrawal and the removal of the needle, a wet antiseptic dressing should be applied or the puncture covered with collodion. If the fluid is thin pus, it is best to insert a needle or canula on either side of the joint and with saline solution continue to wash until the joint cavity is clean. Thick pus or pus with fibrin and detritus should be washed out. If the synovitis has been due to an active septic organism, as shown by fever and local reaction, a drainage tube should be left in the most dependent part of the joint until the infection has subsided.

Acute Infective Synovitis and Arthritis.—Acute infections of joints occur as complications of many constitutional and local diseases, and vary greatly in intensity. They were once called "rheumatism." Some require the

treatment already described for synovitis, others that of exudative synovitis. Aspiration of the fluid is important to relieve tension and check the spread of infection.

Tension, which destroys the capsule and ligaments, and produces metastatic infection should be relieved, by aspirating the fluid from the joint. Thick fluid requires incision or a large trocar.

Pressure of the bone-ends should be relieved by traction. This is accomplished by the methods which are used in the treatment of fractures (see Extension, page 487). Enough weight should be used to overcome the muscular contraction. In the knee that means 5 or 10 pounds. Ankylosis often forms at just the place where the bones press together, and this traction will prevent it. It should be applied at once in all forms of acute arthritis.

By relieving tension and pressure, joint deformity is prevented. For this reason traction and splints are most important.

Autogenous vaccines are of decided value. Streptococcic serum is of service in the streptococcic infections.

When the infection is of an active and virulent type, with pus in the joint, incisions should be made to secure the most thorough cleansing and drainage. The joint should be washed out with salt solution. In the knee, usually two lateral incisions suffice. If drainage from these is not adequate, an incision posteriorly for a tube should be made (see Arthrotomy, page 738).

Before the case becomes desperate and needs incision, the fluid may be drawn off with a needle and the joint irrigated with a 1:500 solution of hypochlorite of calcium, or 10 to 20 c.c. (150 to 300 minims) of a 2, 2.5, 3 or 3.5 per cent. dilution of liquor formaldehyde in glycerin injected. Two or three injections effect a cure. The patient should be kept in bed with traction to the joint for two days after each treatment (see page 487). This treatment should be used before incision and drainage tubes are employed, because the introduction of tubes in these cases means ankylosis in the great majority of cases.

In cases in which the infection continues uncontrolled by these measures, the joint should be more freely opened. In the knee this may be accomplished by the incision for erasion of the joint. A U-shaped incision is made, from one side of the joint to the other, freely opening the joint, dividing the patellar ligament, and turning up a flap containing the patella. The flap is reflected upward, the knee is flexed, and all of its pockets made accessible. The whole synovial lining should be cleansed, and drainage laid in all of its recesses. Tubes and gauze may be brought out through posterior openings, or the whole surface may be covered with a flat layer of gauze and the joint dressed. This packing may be removed under light anesthesia at the end of twenty-four or forty-eight hours, and simple tubular drainage substituted. Later the patellar ligament should be sutured back in place. In desperate and virulent cases this open operation should be the first thing done.

A stiff joint results from the operative treatment of severe inflammations. The best prognosis is secured in the desperate cases by the earliest operation, which may be hoped to control the inflammation before the synovial lining is destroyed. As soon as the infection has been conquered, passive motion and massage should be applied. Good judgment is required in determining when to discontinue drainage and when to begin passive motion. If they are continued after the infection is gone, ankylosis and weakness of the joint progress; if the tubes are removed and motion begun while infection is still present, it is spread and reawakened. There are no rules. Experience

must teach. Usually the temperature, tenderness, swelling, discharge, pain on motion and bacterial examination must be the guides. While such a joint is under observation and a diagnosis of the presence of pus has not yet been made, it should be immobilized and put up in a copious wet dressing of aluminum acetate solution, boric acid, or other antiseptic.

In all acute infective cases, as soon as a diagnosis of pus can be made it should be evacuated. Unless this is done destruction of cartilage and of bone-ends and metastatic infections are threatened.

Acute specific synovitis and **arthritis** are complications of many diseases. *Gonorrheal arthritis* requires immobilization, rest in bed and antigonococcic serum or vaccine. The serum is given in doses of 2 c.c. repeated in from one to four days. Vaccines, preferably autogenous, are of use in recent cases, but not in cases of long standing. Artificial hyperemia by means of hot air, moist heat, the elastic bandage or vacuum chamber is of value. Suppuration demands aspiration or incision, irrigation and drainage. The chronic cases require hyperemic treatment and immobilization; and when persistent and intractable, the hyperemia may best be secured by incision and irrigation of the joint with hot saline solution at 49° to 60° C. (120° to 140°F.). This is one of the most resistant forms of infection.

Besides the local and constitutional treatment of gonorrheal arthritis, the genito-urinary tract should receive attention. Active measures to eradicate the gonococcus should be taken. Often gonorrheal infection of the seminal vesicles is the special lesion which requires attention, and when this is cured the arthritis subsides without further treatment.

Arthritis due to the *pneumococcus* is treated the same as that due to unknown acute infections. *Typhoid arthritis* is treated the same as that of unknown origin. Distention of the joint should not be allowed to occur, and fluid, whether serous or purulent should be evacuated. This is necessary because of the pronounced tendency in this disease to relaxation and destruction of the ligaments. Gentle traction upon the joint should be instituted. This must be watched closely because of the danger of pressure sores. When fluid accumulates the joint should be washed out with 1 : 500 hypochlorite of soda solution. An autogenous vaccine should be given (page 255). The danger of *spontaneous dislocation* in typhoid is very great even when distention of the joint has not been pronounced. The hip especially should be protected from this accident. It should be watched for inflammation, and when found immobilized promptly. The leg should not be allowed to rotate inward as the head of the femur is prone to escape at the back of the joint. The treatment with formaldehyde and glycerin or chlorin solution gives excellent results in these cases.

Arthritis complicating *influenza* requires the treatment given for that of unknown origin. The same may be said of synovitis and arthritis complicating scarlatina, erysipelas, puerperal fever, septicemia, pyemia, tonsillitis, meningitis, diphtheria, dysentery, mumps, epididymitis, glanders, measles, typhus fever, ulcers of the rectum and other infections. The causative disease should be cured.

"Rheumatic" synovitis and **arthritis,** also called "rheumatism," "rheumatic fever," and "acute articular rheumatism," should be treated as a local infection. The joint should be immobilized in the most comfortable position. Hot fomentations are of much value. The joint should be covered with a copious dressing to favor retention of heat. Traction should relieve pressure; aspiration should relieve tension; and the infection should receive the specific treatment which its character indicates. Any of the measures for inducing local hyperemia are of value. The search for the place of en-

trance into the system of the infective agent should be made. Tonsils, nose, rectum, intestine and tooth-sockets should be interrogated, and foci of infection eliminated. If the salicylates have any effect in this disease it is, perhaps, as gastro-intestinal antiseptics, possibly as hemic antiseptics, and by virtue of their antipyretic and heart-depressing properties. When the etiology of this disease is better understood, it will take its place as a surgical disease along with the other joint inflammations.

Chronic arthritis, not due to known specific causes but to the multiple constitutional disturbances which produce new deposits about the joints, must be treated by correcting the disorders of other organs, eliminating foci of infection in other parts of the body, improving the general hygiene, and by local treatment to the joint.

Chronic synovitis is treated the same as chronic arthritis and synovitis with adhesions, depending upon its pathology. Fluid in the joint or loose bodies may be the conditions requiring treatment. Chronic congestion is best relieved by massage. The methods of treatment are described under the various pathological conditions causing or characterizing the synovitis.

Following acute synovitis, muscular atrophy due to disuse or to the inflammation, is a very common sequence, and may be associated with relaxation of the ligaments, causing pain and irritability of the joint. This is common in the knee. To treat this condition with more immobilization, is to increase the muscular atrophy. The best treatment is a few days of absolute immobilization, to insure the subsidence of irritability and then the careful application of massage, passive motion and increasing use of the joint.

Arthritis deformans (rheumatoid arthritis) is a disease characterized by stiffness and pain in the affected joints, usually followed by bony deposits which cause deformity; it is extremely chronic, and tends to be progressive, involving joint after joint. The treatment should be constitutional and local.

The *constitutional treatment* should be aimed to improve the general hygiene. All sources of infection which can be discovered in the tonsils, teeth, nose or gastrointestinal tract should be corrected. Elimination should be made as effective as possible. The bowels should move daily. Warm baths, followed by the cold douch or rub, should be relied on to keep the skin healthy. The intake of food should be carefully regulated to the patient's needs. The several essential elements of the food should be provided. The food should be simple and free from pastry, cooked fats, alcohol, coffee and tea. Tobacco and other narcotics should be dispensed with. Mastication should be complete.

Missing teeth should be replaced with false ones. The amount of food should be the minimum that will maintain health. Intestinal fermentation should be minimized by mastication, moderation, minimum proteids and by the use of lactic acid bacilli. Daily exercise should be taken. The patient should live in the open air day and night with the same zeal that the tuberculous do. This is the reason why many patients are benefited by going to mild climates. The surface of the body should be kept warm.

So much for the general treatment. The surgeon can take hold of any case of arthritis deformans that has been receiving the regulation medical treatment, and produce a decided improvement by stopping the iodid, arsenic, hypophosphates and salicylates and applying the above hygienic measures. The only internal agent which seems to have curative value is extract of thymus gland, 0.6 to 1.2 Gm. (10 to 20 grains) three times daily. At first this makes no impression on the disease; but its prolonged use is possibly of benefit (P. W. Nathan: Jour. Med. Research, 35, 1917).

Of equal importance is the *local treatment.* It cannot be hoped that the

pathologic bony deposits will be removed by any treatment. The most that can be expected is the checking of the progress of the disease. The affected joints should be treated the same as though an infective arthritis were present. Immobilization is the all-important thing.

Immobilization does two important things: it gives rest to the parts and relieves pain. Inflamed joints which are moving cannot get well. Pain interferes with the general health and prevents recovery. These patients should have every painful joint immobilized preferably with a light plaster-of-Paris splint. If there is bad position of the joint, and the case is not too old, the adhesions should be broken up under general anesthesia. The joints should be put up in a position neither of flexion or extension, but somewhere about midway between the two, in a position which is most comfortable and in which the antagonistic groups of muscles are about balanced. When this has been done and absolute rest to the joints secured, the patients usually will begin to eat, sleep, feel better and take on weight.

When immobilization has restored a better state of health, and the joints have ceased to be painful, additional local treatment may then be added to improve the local circulation and metabolism.

Then the induction of local hyperemia is useful. This may be secured best with moist hot applications or with hot air. All of the expedients used in inducing artificial hyperemia and congestion are of service. The hot mud baths, hot sand, steam, etc., have their virtue in this principle. When the pain and tenderness have subsided, massage, exercise, passive motion and vibratory massage should be applied. Electricity is of service. The joint should not be moved or rubbed if these cause pain. Pain is the indication for immobilization.

As the joint tolerates motion and massage they should be increased. Joints should be moved as far as can be tolerated without pain. If pain or swelling appear the joint should be given rest. If the patient is not securing adequate exercise, general muscular massage must be used to take its place. Pain should be the indication for keeping joints quiet. As soon as joints can be used they should be put in motion. Patients should be about as much as possible.

All of the above measures are of importance. It does not suffice to look them over and select something easy. The treatment must be applied with zeal; and it may be relied upon to be of much help in this otherwise intractable disease. One of the pitiful sights in medicine is to see one of these patients put on his bed in a closed room, given the regulation series of drugs, finally have his medication confined to anodynes, and resigned to his fate.

The deformities which follow the disease are amenable to treatment. Joints which are ankylosed in bad position may be put in more useful form by correction under anesthesia. Osteotomy or arthroplasty may be called upon to correct such malpositions. Exostoses may be chiselled off if their presence causes pain or interferes with function. Tenotomies must often be done to improve the condition of joints. Flexion of the knee requires division of the hamstring tendons if it can not be corrected by manipulation and hyperemia. These measures are used after acute symptoms are gone.

Plastic ankylosing arthritis is but slightly amenable to treatment. Discovering and eliminating the cause is of first importance. Immobilization and the induction of artificial hyperemia may be hoped to minimize the synovial destruction. The tendency of the disease is to produce a fibrous ankylosis, which later may be remedied by operation or manipulation (see Ankylosis).

TUBERCULOSIS OF JOINTS

The general treatment of tuberculosis is discussed under Infections (page 276). In tuberculosis of joints, the measures already laid down for increasing the constitutional resistance against the invasions of the tubercle bacillus should be applied. By no means should the surgeon look to local treatment alone to effect a cure. He should think of the local treatment only as supplemental to the general treatment. If the patient is to be cured, and remain cured, his bodily resistance must be made greater than that of the tubercle bacillus.

Another matter of much importance is that mixed infection should be prevented. A tubercular joint is usually a pure tubercular infection. The fact that the infection is present means that the patient is of low resisting power. The tubercle bacillus is overcome with no great difficulty. It requires that the bodily resistance of the patient shall be raised but slightly, and the disease is cured. This can be done in most cases of pure tuberculosis. But with tuberculosis present, meaning that the resistance is low, if there is superadded to it infection with other bacteria of a septic character, these latter organisms not only find local necrosis present, upon which they thrive, but they also encounter a lowered general resistance. Thus when pyogenic staphylococci enter a tubercular zone, suppuration is set up which often becomes prolonged and intractable. In the superficial parts this is not so serious a matter, but in a joint it is. A suppurating tubercular joint is to be avoided by every effort. The absorption of ptomaines of suppuration has a much more depressing effect upon the general health than has tuberculosis. The former *produce* positive lowering of resistance; the latter is the *result* of lowered resistance.

For these reasons a tubercular joint or a pure tubercular abscess should be opened for drainage only when such operation is unavoidable. The operation should be done with scrupulous care, and all subsequent dressings and treatment should aim to prevent infection. Too often tubercular abscesses, leading to joints, have been opened, and in the course of subsequent treatment permitted to become infected with pyogenic bacteria, with the result that prolonged suppuration and sepsis have ensued. Unfortunately, even with the most scrupulous care, this secondary infection is unavoidable in long standing wounds or sinuses.

General treatment is the same as for tuberculosis of bones. Improvement of the general hygiene is most important. Heliotherapy is a potent curative agent.

Tuberculin has the same value in tuberculosis of joints as in tuberculosis of bones. It is probably not of value in the mixed infections in which there is a high and fluctuating temperature. The value of tuberculin and the various anti-tubercular serums in pure tuberculosis is not wholly doubtful. It is wise to give a course of tuberculin treatment preliminary to operation with the view of preventing general tuberculosis which not uncommonly follows operative procedures (see Vaccines, page 255).

Local Treatment.—Local treatment should be applied on the general lines of the local treatment of inflammation (page 228), differing only in the greater precautions against mixed infection as above described. The joint should be surrounded by the conditions which most favor healing and which contribute to the patient's comfort.

Rest is a first requisite, and is aimed to diminish traumatism to the joint. It is secured by (1) fixation, by (2) relieving the joint from the weight of the body in the lower extremities, and by (3) traction to counteract the muscular

pull which draws together the parts of the joint and causes inflamed structures to sustain pressure.

Hyperemic treatment aims to increase local congestion. It is best carried out by the technic of Bier (page 229). Of these methods the passive congestion is most easily applied. In a tubercular joint, the elastic bandage should be applied to the limb above the joint tightly enough to cause a decided obstruction to venous return. The pulse in the artery should not be obliterated. The simple rubber bandage with a layer of gauze beneath should be applied for an hour morning and evening. The bandage should not be left on longer than three hours daily, and this length of time should be reached gradually.

Protection of the joint by means of a smoothly applied flannel bandage is of use in connection with the other methods.

Light treatment by means of strong sunlight or artificial light, and *x-ray treatment* are of value, but of less use than rest and hyperemia. *Heliotherapy* is of great value. It causes local hyperemia; it is locally bactericidal; it increases the somatic resistance; and it brings the patient into the fresh air. Of all the single local measures none is of more value than immobilization with relief of pressure; and next to this the most important is heliotherapy.

The *injection treatment* of tuberculous joints was once much employed after Mikulicz (Berl. Klin. Wochenschr., xviii, 1881) introduced iodoform injections. Fraenkel (Deutsch. med. Wochenschr., May 22, 1902) showed that the effect of these injections was due to the hyperemia caused by their local irritation, and that charcoal was quite as effective as iodoform. The use of 2 or 3 per cent. formalin in glycerin for injecting joints, as advocated by Murphy (see page 281), probably depends for its value much upon the irritation and leukocytosis which it produces rather than upon specific antiseptic action upon the tubercle bacilli. The same may be said of Venice turpentine and of the bismuth and turpentine mixture. The injection into the joint and around the joint of a mixture of 90 parts olive oil, 40 parts ether, 10 parts iodoform, and 2 parts creosote has, perhaps, been of service in curing tuberculosis.

Some surgeons applied the injection treatment to all joints, combining this treatment with immobilization and the other essential measures. In injecting the *hip-joint* it is held in extreme flexion and adduction. The needle is easily passed to the head of the femur above and behind the great trochanter. Continuous extension of the limb is applied after the injection. The iodoform-creosote mixture is as effective as any. There is no evidence to show that these hip cases would not do as well without the injections.

Operative treatment is often called for in advanced cases and when conservative measures have failed. The evacuation of tuberculous abscesses connected with joints is to be deprecated, and should be deferred unless other methods have proved unavailing (see Treatment of Tubercular Abscesses, page 281).

Intra-articular tension may become so great as to demand aspiration or incision to save the joint-capsule from destruction. *Incision* of the joint may also be required to remove necrotic bone or sequestra, or for diagnostic purposes. No matter how much care is taken a tuberculous joint which is drained is apt sooner or later to become infected with other organisms; and it is for this reason that the use of drainage in cases of tuberculosis is objectionable. When it becomes necessary to incise a tuberculous joint, if possible, drainage should not be used but the wound closed with the view of securing primary healing.

Tuberculous foci should be exposed and cureted out when they are dis

tinctly circumscribed and not connected with the synovial membrane. When such foci are large or when they are associated with disease of the synovial membrane, their removal alone is usually not of much service. Where such foci exist, healing may be hastened in some cases by exposing them, curetting out the soft tissue, and sterilizing the wound cavity by means of pure phenol, chlorin, formalin or iodin, and closing the incision.

Arthrectomy means the dissection out of the diseased synovial membrane. It is of service in children, in whom the epiphyseal cartilage should be preserved. Its use is confined usually to the knee and elbow, where all of the synovial membrane is accessible. For a long time it was much employed, but since the more conservative measures have been made so successful the operation is now less used. (For the technic, see Arthrectomy, page 738.)

Excision is used in adults in advanced cases which have proved not amenable to conservative treatment, when the disease is not controlled by hygienic measures and local treatment, when destruction of the end of one or the other bones is present, when a sequestrum has formed and communicates with the joint, when arthrotomy has not served to check the disease or when the general condition of the patient is failing as the local disease progresses. (For the technic, see Excision of Joints, page 738.) This operation, like arthrectomy, is being less and less employed as greater success is being secured with the conservative measures.

Amputation is called for in cases of tuberculosis of joints which have not responded to the methods of treatment already set forth. It is a last resort in cases in which the resistance of the patient cannot be brought up to the point of overcoming the disease. It also becomes necessary in cases which have developed mixed infection and have destruction of bone, sinuses and septic absorption. Amputation is done when it is observed that the patient is losing ground. It becomes imperative when the first signs of amyloid degeneration of the glandular organs appear. The improvement of such a case by amputation is often striking; the patient takes on flesh, and seems to enter upon a state of health which seemed not within the range of hope.

Résumé.—Of the important elements in the treatment of joint tuberculosis, rest is the first to be applied. This means relief of pressure by rest in bed or traction and immobilization by splints or traction. This having been done local treatment should be applied. Heliotherapy and hyperemia are the most effective in the early cases. Along with these measures should go the constitutional treatment. Improved hygiene, nourishment, fresh air and heliotherapy are of the greatest value. Focuses of tuberculous osteitis which are accessible should be cleaned out. Operation is indicated in any case in which no improvement is taking place after five or ten months of immobilization, outdoor hygiene and heliotherapy. Whatever operation is done, the operation should be so concluded as to obviate the necessity for drainage, if possible. If immobilization, traction and protection by means of mechanical appliances can be instituted before abscess or necroses have occurred, these complications will most probably be avoided. Tuberculin, hyperemia, injections and other treatments can not take the place of the more important measures. Above all the improving of the resistance of the patient is the main thing, and should be carried to the highest possible degree.

Tuberculosis of the Hip

The treatment of tuberculosis of the hip-joint is to be carried out upon the general principles already given, excepting that artificial hyperemia can not easily be applied because of the great depth and peculiar situation of the joint. To make pressure upon the obturator, sciatic, internal circumflex

and gluteal veins is fraught with much difficulty. Attempts to produce artificial congestion have not been satisfactory. Treatment is confined to general hygiene and the mechanical protection of the joint. For the protection of the joint are required (1) immobilization, (2) relief from the pressure of the body-weight, and (3) traction to counteract the pull of the strong muscles acting upon the joint.

Acute Stage.—Pain is a most important guide in the treatment of the acute stage. If the joint is painful; if there is much irritation of the muscles, causing strong contraction; if the swelling is pronounced; or if ambulatory treatment is not controlling the disease, the patient should be treated in the recumbent position. It is always wise to be on the safe side and treat all cases in the acute stage by the recumbent method.

For immobilization purposes, in children, it is best that the patient should be put on a recumbency frame, such as devised by E. H. Bradford (Fig. 483). This is made of 1.5 or 2 cm. (⅝ or ¾ inch) gas-pipe. It should be about 2.5 cm. (1 inch) wider than the width of the hips, and 15 cm. (6

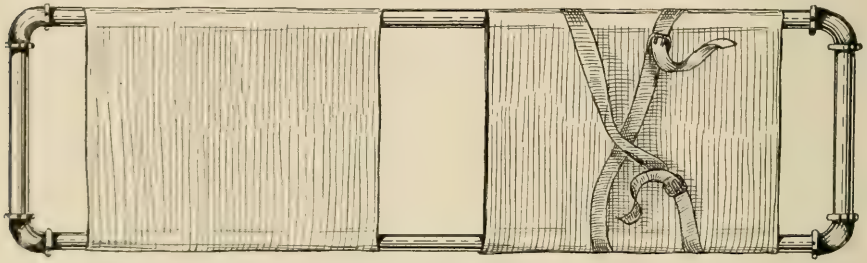


FIG. 483.—RECUMBENCY FRAME, MADE OF GAS PIPE AND COVERED WITH CANVAS, FOR TREATMENT OF TUBERCULOSIS OF THE HIP AND SPINE.

inches) longer than the length of the child. The frame should be covered with two pieces of canvas tightly laced across it, leaving a space between them for the use of the bed pan. A smooth towel is spread on the canvas. The child should be made fast to this frame by the chest straps and by a pelvic binder. Extension by means of adhesive straps, weight and pulleys should be applied, after the manner described in the treatment of fracture of the thigh. The traction should be made in the direction of the long axis of the femur in the position assumed by the patient as giving the greatest comfort. This is usually in flexion, varying in degree. An inclined plane should be placed under the thigh to support it. The weight of the extension traction should be just sufficient to give the greatest comfort, usually 2 to 5 or 10 pounds, rarely 15 pounds. Once a day the child should be turned over on his well side to have the sheet or towel under him smoothed out and his back bathed and rubbed. For the methods of making traction to the lower extremities, see Traction in Fractures, page 487.

It is most important that the patient shall be kept out of doors. This may be done by placing the bed in the open, or the frame may be lifted up and carried with the patient. If the pulley of the extension weight is attached to the frame, instead of to the bed, the whole apparatus is easily moved from one place to another without disturbing the patient, the position of the limb or changing the traction. There are many ways for accomplishing this. The frame may rest upon a board, from the foot of which an upright springs, bearing the weight and pulley; or the frame may be made with an extension of tubing to which pulleys are attached. In order to facilitate getting children out of doors, I have devised two forms of frame for this

purpose (Figs. 484 and 485). With such a frame the patient may be out of doors in all weather when it is cold, he may be brought into the house when bathed or when required to be uncovered to use the bed pan.

The flexed limb should be lowered gradually, the flexion of the hip being made less and less as the pain and muscular contractures subside. The limb can usually be brought down straight in the course of two or three weeks.

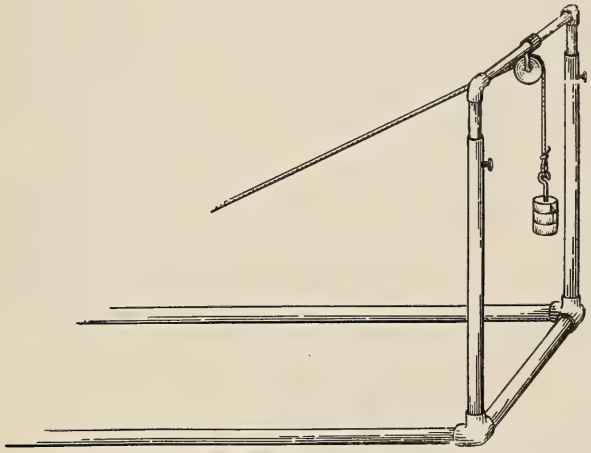


FIG. 484.—FRAME OF TUBING, DEVISED BY AUTHOR, WHICH PERMITS THE PATIENT TO BE CARRIED OUT OF DOORS WITHOUT DISTURBING THE TRACTION.

The degree of elevation of the limb may be regulated.

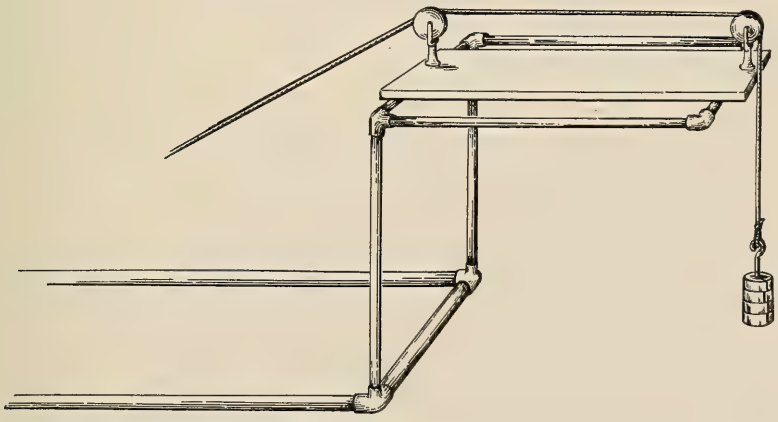


FIG. 485.—PORTABLE FRAME OF TUBING WITH TRACTION ATTACHMENT, DEVISED BY AUTHOR,

The patient may be taken from the frame along with the traction apparatus.

The lowering should first be attempted at the end of the first week while the extension is being continued. If no pain is caused, the limb should be lowered about halfway toward its natural position. It should be stopped just short of causing pain. At the end of the second week, it should be lowered still further; if possible, to the horizontal position. As this is done, the pulley over which the traction cord passes should be lowered. If these movements cause pain they should be discontinued.

In order to supplement the extension by immobilization, the pelvis should be bound down to the frame by a broad band. If the ideal extension apparatus cannot be had, a wooden frame may be made; or none at all may be used. If no extension can be applied, immobilization may be secured by means of a long side splint, a Thomas' hip-splint or a posterior inclined plane. The majority of cases which are immobilized in a comfortable position do well even without traction, and the flexion can be overcome gradually just as in the treatment with traction. The patient should be kept recumbent until the acute symptoms have subsided. In carrying out this treatment it should be remembered that the comfort of the patient is the main thing, and serves as the best indication that treatment is progressing along the right lines. When immobilization alone is tried, and the patient has pain, traction should be applied.

If in the first stage of the disease the symptoms are not acute, it is still best to be on the safe side and treat the case in the recumbent position for a time until, at least, the surgeon gets in touch with its progress and is sure that the disease is under control. But in no stage is recumbency of more importance than fresh air; and if treatment in bed makes it impossible for the patient to be in the open air, then it is usually better to forego the recumbency and apply some of the methods for immobilization used in the subacute stage.

Subacute Stage (Convalescent Stage).—As soon as the conditions calling for recumbent treatment have passed, the patient should be fitted with some form of splint for immobilization and gotten up and about. The ambulant treatment is to be adopted as soon as is consistent with the conditions set forth above. In most cases after two or three weeks, when the flexion has been overcome, the patient can be gotten up. Usually only immobilization, without traction, is required. It is well to determine this by continuing the splint immobilization for a few days after the leg has been brought down straight and traction has been removed.

If immobilization alone of the hip-joint suffices to give comfort, the cheapest and most satisfactory splint to accomplish this is plaster-of-Paris. The skin from which the adhesive strips have been removed should be treated with antiseptic powder. The leg and trunk should be covered with tricot cloth or cotton underclothing, the patient placed on a pelvic support and a plaster case applied from the middle of the calf nearly to the axilla (Fig. 486). This splint does not require to be thick. It should be snugly applied around the pelvis and over the trochanter. Opposite the hip or groin it should be strengthened by incorporating strips of thin wood, wire mesh or perforated tin (see Plaster-of-Paris, pages 57 and 477). The thigh should be in slight abduction. In young children, to prevent soiling, the plaster may be painted with water-glass or shellac and the space about the pelvis closed with adhesive plaster.

The *ambulant treatment* may be used in connection with this dressing. This is secured by incorporating the iron foot-piece in the plaster case, adhesive strips having been applied to the thigh. Traction is made by rubber elastic bands attached to the foot-piece (Fig. 489). A lift of 6 or 8 cm. (2½ or 3 inches) should be put under the sole of the shoe of the sound side, and the patient allowed about on crutches. The foot of the lame side should not touch the ground.

Instead of plaster, a good splint can be made of sole leather, or, for younger children, loop-leather. This is made to embrace the same parts as the plaster-of-Paris. A paper or cloth pattern is made and the leather cut accordingly. It is soaked in water until it becomes pliable and then put on. It should be bandaged snugly to the parts, and when it becomes dry it will

be found stiff and firm. Instead of holding it on with bandage, the edges may be united with laces or straps and buckles. It may be made firmer by varnishing its surface when dry. Many other materials lend themselves for this purpose, such as celluloid, felt and paper; but none are so easily managed as plaster-of-Paris. The latter when soiled or broken may easily be renewed.

FIG. 486.—TUBERCULOSIS OF HIP.
Plaster-of-Paris splint in treatment of convalescent stage. Note abduction of thigh.

The Thomas hip-splint is excellent, but to be effective it must be exactly applied. It cannot be said that it gives as good immobilization as the plaster splint. In the hands of those skillful in its use it gives good results.

In many cases it is desirable to keep up slight extension, and for this purpose the so-called traction splints are used. They do not give perfect immobilization, but the advantages of extension and ambulant treatment compensate for this disadvantage. The splint in common use consists of a horizontal pelvic band, an upright passing down the outer side of the leg, a

band for the thigh and calf and two perineal bands. The pelvic band grasps the pelvis snugly just below its brim and is inclined so that its front is about 20 degrees lower than the back. The upright passes down about 6 cm. (2½ inches) below the heel of the foot and is turned inward at a right angle. Adhesive straps are attached to the thigh as in the treatment of fracture of the neck of the femur and held on with bandage. The lower ends of these straps are fastened to the lower end of the splint in such a way as to make slight traction, the countertraction being made with the perineal bands.

FIG. 487.—TRACTION SPLINT WORN IN CONVALESCENT STAGE OF TUBERCULOSIS OF HIP.

FIG. 488.—LOVETT'S HIP SPLINT WITH CUIRASSE.

Traction is made by constructing the rod in two pieces, one passing into the other and providing it with a cog and ratchet to secure lengthening, or by attaching the adhesive straps to a strap or cord which is wound with a key about a spindle under the foot.

The traction splint when worn permits the patient to go about with crutches, a lift of 6 cm. (2½ inches) being placed under the sole of the sound side. Later the weight of the leg alone gives sufficient traction (Fig. 487). This splint requires close watching. The perineum must be kept dry. The traction must be kept in constant operation. It is worn day and night, and removed only to give attention to the skin.

As healing progresses, the patient may begin to bear weight upon the splint, and finally walk upon it and lay aside the crutches. When used in this way care should be taken that the foot does not rest upon the ground piece. At first the joint between the upright and the pelvic band should be immovable; later motion may be permitted.

A modification of this splint has been made by carrying it higher and adding a breast band. R. W. Lovett made a decided improvement by combining it with a cuirasse, thus securing for it the advantage of better immobilization (Fig. 488). Whichever splint is used of the two, immobilization is more important than traction; and bad results often obtain because the efforts to secure both end in poor immobilization.

The *ambulatory treatment* may be used after the acute stage has passed, but never during the acute stage. It should give especial attention to fixation, traction and protection. These are the essentials of the mechanical treatment. The plaster-of-Paris spica bandage, adhesive strips, connected to a traction mechanism and the iron brace which extends below the foot may be combined to meet these three requirements. Adhesive strips for traction are placed along the lower three-fourths of the thigh; the child's body and thigh are covered with tricot, jersey or stockinette cloth, with three or four extra thicknesses of the same cloth over the anterior-superior spine of the ilium and the tuberosity of the ischium; and the patient is placed on the hammock frame face downward. This frame is of tubular iron, and has stretched over it a piece of cotton cloth on which the child lies. Traction should be made longitudinally by an adhesive plaster strip as in the treatment of fractures. Counter-extension is made by a band under the arms; and gentle lateral abducting traction should be made on the upper part of the thigh. Slight abduction should be maintained. In this position a plaster case is applied from the axilla to the knee.

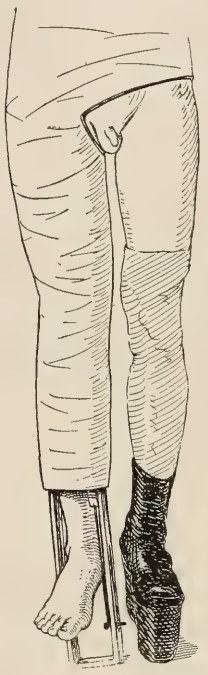


FIG. 489.—TRACTION SPLINT FOR AMBULATORY TREATMENT OF TUBERCULOSIS OF HIP-JOINT.

A plaster-of-Paris case is applied in combination with traction, secured by adhesive strips connected to the iron extension by rubber elastic bands.

The brace used should consist of two lateral flat iron strips connected by a ratchet to a crosspiece which passes below the foot. The brace is bent so that it will conform to the plaster-of-Paris case. The foot-piece should be about 6 cm. (2½ inches) below the sole of the foot. The brace is attached to the plaster case with a strap and a few turns of plaster bandage. The adhesive plaster strips are attached to the foot-piece and the latter screwed down to make gentle traction as soon as the plaster-of-Paris has hardened; or traction may be made by means of rubber elastic. A thick-soled shoe is placed on the other foot; and with crutches the patient may go about (Fig. 489). He should bear his weight only on the well leg. The object of the splint is to provide only fixation, traction and protection. It maintains these and especially protects the joint against any accidental injury even though the child is going about.

This treatment does not give perfect immobilization. There is dis-

agreement among orthopedic surgeons as to whether immobilization in the first place is possible and whether in the second place it is desirable. It is possible that a certain amount of motion is beneficial in the treatment of hip-joint tuberculosis. Most surgeons are of the opinion that the more perfect the immobilization, the better.

Convalescent Stage.—A peculiarity of this disease is its tendency to recurrences and exacerbations if treatment is relaxed before the infection has disappeared. As the disease subsides, pain, afternoon temperature and spasm cease, and cicatrization takes place. Rigid treatment is no longer demanded; but it is important that the joint shall be protected from traumatism. The traction splint may be continued, but traction through the adhesive straps may be dispensed with. The splint should serve for immobilization and for the purpose of keeping the foot from the ground. It may be worn with a shoe, and a joint may be made at the knee.

The splint should be worn at least two years after the subsidence of the active symptoms. Tests with tuberculin are of service, but the surgeon must be guided much by the local conditions. When there seems to be no more pain or other symptoms, and when the joint seems to have been immobilized a sufficiently long time, the experiment of leaving off the splint may be made. At the end of a week, if no symptoms have developed, the joint should be tested; and, if its range of motion has increased, it is probable that the disease is cured. If, without the splint the range of motion has decreased or pain has developed, then protection should be given to the joint for a while longer.

By using in the latter part of the disease the so-called traction splint without the traction, and by gradually adding motion at the knee and at the hip by means of joints in the apparatus, the restoration of the limb to its natural functions may be approached slowly. Whatever method is in use, any exacerbation of symptoms should be met by a return to more rigid immobilization or traction. Fresh air in the open, simple, nourishing diet and general attention to the hygiene should never be lost sight of whatever the local treatment.

Complications.—The complications most commonly requiring treatment are abscess and deformity.

Abscess, springing from tuberculosis of the hip-joint should be treated along the lines already laid down (see page 281). Exceptions to the general rules must be made when the abscess is very large, involves the great vessels or nerves or is so situated as to interfere with the necessary immobilization and traction. Aspiration is often called for. When a case is treated properly from the beginning abscess should but rarely occur.

Deformity, due to muscular contracture, requires attention chiefly in cases which have not come under proper treatment in the early stage of the disease. These cases are sometimes found with pronounced flexion. When tuberculosis is still present the patient should be treated the same as an early case; traction should be made in the direction of the long axis of the flexed thigh. Each week the limb should be lowered and traction continued until the desired position has been secured.

Cases in which pain is not a feature may be treated by immobilization without traction. The position is partially or wholly corrected and a splint of plaster-of-Paris applied. The patient is kept quiet for two or three weeks, and, if necessary, further correction made. Older cases with fibrous ankylosis can be corrected only under general anesthesia by this means. In these cases the force should not be too strong; it should be applied only in one direction; and it should stop short of doing too much damage. Often contractured muscles and fasciæ will require to be divided.

Still older cases, in which all infection has subsided and left fibrous ankylosis, may be treated with greater force. If correction can not thus be made, better position of the limb is secured by subtrochanteric *osteotomy* (see Osteotomy of the Upper End of the Femur, page 713). Following osteotomy, the limb should be brought down to the desired position and put up in plaster-of-Paris extending from the toes up to the nipples. The same length of time should be given for the healing of the bone as for any other fracture of the femur. The results for this operation are good.

In later years the operative treatment of ankylosis has been applied to some of these cases with the result of securing a movable joint. This is the ideal treatment of the cases healed with fibrous ankylosis (see Ankylosis, page 765).

Uncontrolled shortening of the leg is met by wearing a lift under the shoe. But no patient should be condemned for life to distortions due to faulty joint position.

Operative Treatment.—*Arthrectomy* is not attempted in the hip.

Excision of the hip is called for only in exceptional cases (see page 748). Its special indications are the existence of sinuses or sequestra. The results are variable, but a weak and unsatisfactory joint often results. The incision for excision may be that of the surgeon's preference. If sinuses exist posteriorly, it is best to use a posterior incision; if sinuses open anteriorly, an anterior incision is to be preferred. All diseased tissue that can be found should be removed, dead bone curetted and channels of infection followed up and excised.

In adults the operation is called for much more than in children. But in children, if the infection remains purely tuberculous, it is surprising how much may be accomplished by conservative measures.

Amputation is reserved as a last resort for cases which continue to do poorly under other treatment (see page 665). It is more commonly called for in adults, but should not be denied younger patients. The mortality is high because the operation is done upon feeble subjects. The high mortality cannot be attributed to the operation, but to the disease which the operation fails to control.

Tuberculosis of the Hip-joint in Adults.—Because of less active reparative process in adults, tuberculosis of the hip offers a poorer prognosis. Treatment must be carried out most rigorously. The mental state and the general hygiene are matters of great importance. The Thomas splint, well secured to the pelvis and thigh in order to give the best immobilization, allows the patient to be about on crutches with a lift under the sound foot. When improvement does not progress excision should be done, and the destruction of such disease as can not be removed by chisel or curette attempted by local medicament (see page 280).

Double Hip-joint Tuberculosis.—The second joint usually becomes involved while the first is under treatment, and in the hands of a watchful surgeon comes early under immobilization. A longer period of recumbency is entailed, but the prognosis is not made especially worse by the complication. The same treatment is applied to either hip.

Résumé.—Rest, extension, good nursing and hygiene, and outdoor air are the important elements of treatment. In children there need not be a mortality above 5 per cent. Excision or amputation need never be contemplated in cases placed under treatment before the need for such mutilation has become imperative. Absolute rest in the early stages is important. The joint should not be moved. The child should not be allowed to sit up. If necessary for immobilization of the joint, splints should be added to the

extension. Extension should be made at first in the direction of the long axis of the femur in the position in which there is the greatest comfort. Ultimately the limb should lie horizontally as the muscles become relaxed. This is important in order to have the limb in the best position for use in case ankylosis of the hip occurs. For immobilization and extension but little weight is required. More than 2 pounds is rarely needed in children. Some are made comfortable with less than that. Occasionally a child requires 3 or 4 pounds for a short time, after which the amount may be reduced. Pure tuberculous abscesses should not be incised. Mixed infections, giving irregular fever, should be opened carefully.

Tuberculin is undoubtedly of value. Heliotherapy is also of great service. The injection of antiseptic irritants is capable of producing healing hyperemia, but it may do more harm than good and cannot be regarded as a routine measure. The child should not be allowed to walk on the leg, bearing the full weight of the body on the hip, for at least a year after it is well enough to be about with crutches.

FIG. 490.—TUBERCULOSIS OF KNEE, TREATED IN PLASTER-OF-PARIS CASE.

TUBERCULOSIS OF THE KNEE-JOINT

Tuberculosis of the knee-joint is treated upon the same principles as tuberculosis of the hip-joint. The prognosis of the former both for life and function of the joint is better than the latter. The disease is easily recognized and should come early under treatment. Immobilization, artificial hyperemia, protection from traumatism and traction are the local measures of reliance which are added to the general hygienic treatment (page 276).

Immobilization is best accomplished by a plaster-of-Paris case extending from the upper third of the thigh to the malleoli. This is applied by means of plaster bandage over tricot, a stocking or a drawer leg. With a lift under the other shoe the patient may go about with crutches. No weight should be borne upon the diseased joint. This treatment alone in cases without deformity or pain will usually suffice to effect a cure (Fig. 490).

Decided advantage is to be gained by combining artificial hyperemia with immobilization. To do this a removable splint becomes necessary. Plaster-of-Paris lends itself to this end. The plaster case is split down on its inner and outer sides and removed in the form of an anterior and posterior half. Six millimeters (¼ inch) are cut away from the edges of each half, and the edges are bound with a strip of adhesive plaster or plaster-of-Paris. This splint

may be supplied with hooks and laces, straps and buckles, or it may be held on by a simple bandage. When removed each day for the application of the hyperemic treatment care should be taken not to bend the knee. After the treatment or during the treatment the splint is replaced. A new one is made when the old one ceases to fit well or becomes soiled (see Plaster-of-Paris, pages 57 and 477).

Other materials, lighter than plaster, may be used (see Splints, page 56). Celluloid, leather and paper lend themselves for this purpose. Splints of these latter materials are best made over a cast of the plaster case. A thin plaster bandage is put on, allowed to dry and removed by splitting it down the front. Plaster-of-Paris is poured into this, and over the cast thus made a splint is constructed. These lighter materials need only be cut down the front and laced.

Artificial hyperemia may be applied by means of the constricting bandage or by means of the vacuum knee cup (see page 232). Instead of these methods, dry or moist heat is of service (see Inflammations, p. 228). The use of these measures should not interfere with the other essentials.

Heliotherapy is especially effective in knee tuberculosis, and may be used in conjunction with immobilization.

Protection from traumatism is secured by an immobilizing splint and by refraining from bearing weight on the diseased leg. In the case of an adult, it can be secured by the immobilizing splint, a lift under the other foot and crutches. But with children the temptation to put weight on the diseased limb is so great, that further protection must be secured. A splint which reaches below the foot, which will sustain the weight of the body, and which rests against the perineum and pelvis above, is used. The so-called Thomas' knee-splint (Fig. 383) fulfills these indications. It consists of a perineal ring, two lateral bars, a foot-piece and straps. The ring is made to fit the hip region of the thigh, connects the two bars and slopes downward and inward. It should be well padded and kept dry and clean. The splint should extend about 5 cm. (2 inches) below the sole. A strap passes posteriorly behind the knee and the ankle and connects the two lateral bars. A padded bandage of leather surrounds the limb above and below the knee. The measurements for this splint should be taken from a point 7 or 8 cm. (3 inches) below the sole to the perineum on the inside, and on the outside to a point midway between the crest of the ilium and the great trochanter. The apparatus is suspended from the ring before and behind by a webbing band passing over the opposite shoulder.

The best results are secured by combining this with a light immobilizing splint of plaster-of-Paris or other material. With the Thomas splint put on over it, and a lift on the other shoe, the patient can walk without crutches, the weight of the body being borne by the ring pressing against the pelvis. Crutches are advisable in most cases. This is used after the acute stage and during the subsidence of the disease.

Traction is used when there is much pain which is not relieved by immobilization and when contracture deformity is present. When the limb is straight and traction is required, it may be applied by means of the Thomas or Taylor splint. Adhesive straps are attached to the skin of the leg and connected by means of straps or elastic bands to the foot-piece.

Flexion deformity is present in many cases when first seen by the surgeon. The treatment of this condition must be carried out before the above described ambulatory splints can be used. If the joint is painful, *traction* will give the best result. It should be applied by means of adhesive strips attached to the skin below the knee after the method used in fractures

(see page 487). The traction should be nearly in the direction of the long axis of the flexed leg. This is accomplished by putting the thigh and leg on an inclined plane (Fig. 491) to elevate the knee. Every week the knee may be lowered to the last degree of comfort, until by the end of two or three weeks the limb is straight. Then, if upon the removal of extension there is no pain, the patient may be put in the ambulatory apparatus.

Many patients when seen early have flexion and little or no pain. Such cases may be put immediately in a light plaster-of-Paris case, some correction

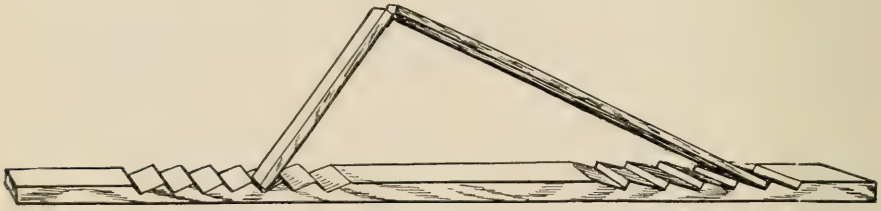


FIG. 491.—DOUBLE INCLINED PLANE FOR GRADUAL EXTENSION OF KNEE TO OVERCOME FLEXION DEFORMITY.

being made at once. At the end of two weeks the splint may be removed, more correction made and another applied. This process is repeated until the limb is straight. Pain should not be produced. In no case of correcting disease of the knee should extreme extension be used; it should always be stopped just short of the full extension and the joint held with a slight suggestion of flexion.

In *old cases*, cured or convalescent as to their tuberculosis, with flexion deformity, in which neither traction nor gradual correction are of service

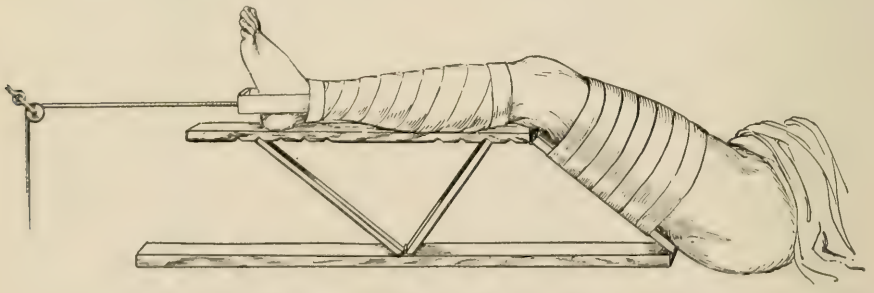


FIG. 492.—TUBERCULOSIS OF KNEE.
Traction and correction of flexion deformity. Thick padding should be placed between the limb and the splint.

because of the firm adhesions and muscular contractures, correction must be attempted under anesthesia. In performing this operation of forcible extension, forward pressure must be made at the same time upon the upper end of the tibia to prevent its backward displacement. If the hamstring tendons offer resistance to correction, they must be divided subcutaneously. Forcible extension should not be made if active disease is present or if there are sinuses and suppuration.

Correction by *gradual extension* is applicable in cases in which the resistance is not too great. It may be applied by weights and pulleys (Fig. 492).

Osteotomy of the femur above the condyles is practised in cases of ankylosis not amenable to the above measures (see Osteotomy, page 714). The transverse operation is done, the bone broken, the lower fragment flexed enough to make the limb straight and a plaster case applied. This is by no means an ideal operation, but it is much better than an uncorrected flexed knee. The shortening is inconsiderable; and a strong limb is secured.

Some surgeons have operated by the *removal of a wedge of bone* from the knee, with the base forward, and secured bony union as in excision of the knee-joint. The newer operations of *arthroplasty for ankylosis* are of much more service.

Convalescence.—Whatever treatment is applied during the acute and later stages of the disease, convalescence should be recognized. When spasm and pain have been absent for from four to six months, the splint may be removed, and the joint allowed at liberty. If there is no return of pain, and from day to day the arc of motion increases, a cure has been secured. If without the splint, there is a return of muscular spasm and pain, the splint should at once be reapplied. This stage must be closely watched lest the joint be used too soon. The surgeon should not be deceived by a certain degree of swelling which usually takes place when the splint is removed even when the disease has been entirely cured.

In spite of treatment in some cases, the disease progresses and the joint becomes worse. If every possible necessary measure of hygiene, general and local treatment have been secured, and the disorganization of the joint persistently progresses, operation is called for. The operations are arthrectomy, excision and amputation.

Arthrectomy is used in the case of children. It is a valuable operation, and when thoroughly done gives satisfactory results (see Arthrectomy, p. 710). In adults, when the operation reveals disorganization of bone, a typical excision may be added. The objects of both of these operations is to remove all of the disease and to secure ankylosis; and a combination of the two is often called for.

Excision is most commonly called for in adults. When performed in children the epiphyseal line should be preserved; if it is destroyed the longitudinal growth of that end of the bone is checked, and distressing deformity results. (For technic, see Excision of the Knee-joint, page 749.)

Amputation is a last resort. Its object is to save the life of the patient. It is called for after hygienic, general and local treatment have failed, and excision cannot sufficiently eradicate the disease in patients over forty-five years of age. It is true that in former times many amputations were done which would not have been neccessary had the patient lived out of doors day and night. The number of amputations which are now called for are much fewer since the hygienic treatment has been applied. But when, despite the best treatment, the disease continues to progress, the patient to lose ground and sinuses to remain unhealed, a final attempt at local resection may be made; and if it is clear that this cannot eradicate the disease without leaving a useless limb, then amputation should be done. Amputation should be done immediately in cases in which it is clearly evident that local treatment cannot be of avail, or in which the general condition of the patient calls for the removal of extensive septic foci.

Abscess.—The treatment of abscess is the same as that in the hip. It is discussed under the head of Tuberculosis (see page 281).

Tuberculosis of the Ankle-joint

This disease usually begins in the adjacent bone, astragalus, tibia or os calcis, and least frequently in the synovial membrane. Eventually all of the structures may become involved. The treatment is rest, immobilization and protection. The prognosis in children is favorable; in adults it is much worse, and unless the disease is arrested there is a tendency for it to become complicated by pulmonary tuberculosis.

A case when first seen in an early stage should have applied an immobilizing splint. For this purpose plaster-of-Paris is well adapted. Such a splint should extend from the toes up over the upper third of the leg. The plaster splint may be sprung off by cutting it down in front; using it as a mould, a plaster cast, having the shape of the ankle, may be made. Over the cast a splint of leather, of paper and glue or of celluloid may be shaped. Such a splint should be made removable by being provided with laces down the front. The foot should be fixed in the most comfortable position, which is generally the position in which it is found. If a bad position exists (*i.e.*, any position other than with the foot at a right angle) it should be corrected gradually, provided such correction can be made without pain.

A removable splint having been provided, the patient should be instructed to be about with crutches, taking care not to contuse or put any weight upon the ankle. To further these ends a lift should be put under the shoe of the sound foot, or a Thomas knee-splint may be worn and the weight of the body transmitted from the ground to the pelvis.

Artificial hyperemia or heliotherapy should be combined with the above described treatment

As the disease becomes chronic *abscesses* may develop. Such abscesses are best treated by wide incision and simultaneous removal of all diseased bone. When operation is done it should be complete; afterward, the dressing and bandage usually give sufficient immobilization until the wounds are healed.

When healing fails to progress, even though no abscess has developed, *operation* is called for just as in tuberculosis of the knee. Division of the tendo Achillis may be called for in spasm of the sural muscles. If the *x*-ray has revealed the location of diseased foci, they should be exposed and removed with the curette. If the synovial membrane as well as the bone is involved, *excision* of the joint will be of most service. Operative eradication of the diseased foci or diseased parts of bone should not be delayed in adults (see Excision of ankle, page 753). *Amputation* is called for under the same condition as described in connection with the knee-joint. In adults, amputation becomes necessary in a large proportion of the cases which come to the surgeon after destruction of bones has taken place.

Under better hygiene and the inducing of hyperemia, the necessity for operation is much reduced in these cases.

In a child under four years of age fixation and protection alone with hygiene can be expected to effect a cure. A year at least must be consumed in the treatment. In the young, aspiration of abscesses should be tried before incision is resorted to. Sinuses in children may be multiple and extensive, but the surgeon may hope for their ultimate cure even though several years are required. If good drainage is provided the constitutional harm need not be great. Amputation is rarely justified in a young child.

The conservative non-operative treatment should always be pursued in preference to operation in children. Under the nonoperative treatment, there is less danger of secondary deposits and general tuberculosis, deformity is less, and less time is required in treatment. Heliotherapy is of especial value in children.

Tuberculosis of the Shoulder-joint

In children, immobilization may be expected to effect a cure. To this should be added general hygienic treatment and local hyperemia. Heliotherapy is of great value. Immobilization is easily secured by a simple bandage or binder fixing the upper arm and forearm to the chest. The hand may be left at liberty, and also the forearm, excepting in connection with such motions as cause movement of the humerus. Thus all of the motions of the hand and wrist are allowed, together with rotation, flexion and extension of the forearm, but they must not produce rotation of the humerus. To be sure of this control of the humerus in a child, it is necessary to confine the forearm.

In cases in which pain is not controlled by immobilization, traction will sometimes be of service. This is applied as in fractures of the upper end of humerus; the weight need not be much.

Artificial hyperemia is secured by means of the round rubber tourniquet tightly thrown about the shoulder, and held inward by means of a loop of bandage behind and in front. Whatever treatment is applied, it should not interfere with the employment of hyperemia (see Artificial Hyperemia, page 229).

When the disease proves intractable, operative treatment is called for. In children it is rarely necessary; and when demanded, should consist in exposure of the joint by anterior, straight incision, curettage of the diseased caput humeri and excision fo diseased synovial membrane and such other parts as are affected. In adults a more extensive removal of the head may be practised, typical excision giving the best results. The operation, if done in an uncomplicated case should be concluded by closure of the wound; if the infection is a mixed one or if sinuses have been present, drainage should be provided.

Tuberculosis of the Elbow-joint

The first treatment to receive consideration in this joint, after general hygiene, is artificial hyperemia and heliotherapy. Heliotherapy is of great value. Immobilization is important, but it should be maintained by a splint which is easily removed for the local treatment. The forearm is carried in a sling. A plaster-of-Paris casing may be applied over a cotton shirt sleeve from the wrist to the axilla. The elbow should be in a comfortable position, preferably at a right angle and the thumb directed upward. This splint may be split down behind and in front, hinged on one side, and laced on the other, to facilitate its daily removal for hyperemic treatment by means of rubber bands or heliotherapy.

Aspiration, medicinal injection, incision and drainage, and excision are all of especial value in this joint. If healing is not progressing satisfactorily under the above treatment, operation should not be deferred. Immobilization offers less, and operation offers more in this joint than in the knee and hip. Hyperemia wins some of its most promised successes here. Operations for drainage and medication not sufficing, excision is called for. The posterior incision, with temporary division of the olecranon gives best access to the joint (see Excision of Elbow, page 742). The diseased bone is best sawed away until healthy bone is exposed. This should be done with all of the diseased bone-ends. The tuberculous synovial membrane should be dissected out. It is only necessary to remove the tuberculous bone; a complete and typical excision is not always called for. The use of the Esmarch bandage to make the operation bloodless is of service. The olecranon is sutured back in place and the arm put up in plaster at a right

angle with the thumb upward. If sinuses were present, drainage is used. Immobilization should be maintained for a month. Too early passive motion is more apt to cause ankylosis than to prevent it.

Tuberculosis of the Wrist-joint

The same general principles of treatment are called for here as in the ankle-joint. They are hygiene, immobilization by splint, artificial hyperemia, heliotherapy and excision in intractable cases. A splint of plaster-of-Paris, hinged on one side and laced on the other, or simply held by straps, is best. This can be removed daily for the hyperemic treatment (see page 578). The splint should extend from the knuckles to just below the elbow. The fingers should be left at liberty. The forearm should be carried in a sling.

In children the prognosis is fairly good. In adults operation is often called for because the cases come to the surgeon late. When the local treatment fails to clear up the disease, excision should not be delayed as these patients seem especially prone to develop tuberculosis of the lungs. Excision should be wide and complete, and when begun should aim at the removal of all tuberculous structures. If all of the disease is not removed, injections and applications with antituberculous medication are of service.

Tuberculosis of Metacarpal, Metatarsal and Phalangeal Joints

The treatment in these joints is to be conducted by rest, hygiene, hyperemia, heliotherapy and the same general principles as are applied to other joints. There is one exception to this rule: excision and amputation should be resorted to earlier if healing is not prompt. A tuberculous focus is always a source of danger, and in many cases it is better to eliminate it *in toto* and at once, provided this can be done without a crippling operation. In the case of these distal joints such an operation can often be done without much damage to the efficiency of the patient.

Tuberculosis of the Sacro-iliac Joint

Rest and protection are given to this joint by rest in bed, combined with weight and pulley extension if the symptoms are acute. The extension should be applied to the pelvis, not to the thighs. This condition should have the same treatment as is given to tuberculosis of the bodies of the vertebræ. The only method by which weight may be taken from the diseased joint is by a corset or traction apparatus which makes downward pressure upon the pelvis and upward pressure on the axilla and thorax. The joint may be immobilized by means of a plaster-of-Paris, paper or leather splint, embracing the pelvis and thighs and extending from just above the knee up to the axillæ. Hyperemia is applied by means of suction cups. Heliotherapy is of value.

Failure to respond to treatment, or the appearance of abscess, should call for operation. When the joint is opened all tuberculous disease should be removed, and immobilization maintained until healing is secured.

SYPHILIS OF JOINTS

The recognition of this condition and its differentiation from tuberculous and other arthritides having been accomplished, the treatment is simple. The patient should at once be brought under the influence of antisyphilitic treatment. If there is great pain, the treatment must be rapidly pushed. An acutely distended joint may require aspiration. If breaking down of

bone and the formation of sinuses have occurred, the ordinary surgical measures for their correction are called for. The constitutional treatment is the main thing.

NEUROPATHIC JOINT CONDITIONS

Tabetic Arthropathy (Charcot's Joint Disease)

The treatment of this disease is apt to prove its intractability. The causative factors should receive first consideration. Tabes should have done for it all that is possible. The best personal hygiene should be secured. Immobilization of the joint during the early stage of the disease is of service. For this purpose, the local treatment which is employed in tuberculosis of the joint is applicable. Protection from the traumatism of motion and weight-bearing has proved of help.

Neuromimesis of Joints

These joint neuroses, often described as hysterical joints, demand a correct diagnosis for successful treatment. The surgeon should beware lest an actual pathological change in the joint be responsible for the symptoms, and the patient be encouraged to use a joint which should have rest. The *x*-ray should aid in discovering disease of the bone.

No good will come from telling these patients that nothing is the matter with their joints. The surgeon's attitude should be one of scientific interest. The patient should be informed that there is a defect of the nerve supply or circulation of the joint. The general hygiene should receive attention. Any source of irritation to the nervous system should be hunted out and remedied. The eyes, the sexual organs, the nervous system, autointoxications, etc., should be thought of.

The patient should come entirely under the control of the surgeon. It is best that she should be treated away from the environment in which the disease developed. Pain and deformity require treatment. For these some mild measures which slightly stimulate the local circulation are best. Dry heat, artificial hyperemia, vibratory massage, electricity, rubbing, etc., are of service.

Contracted muscles may be relaxed by massage. In pronounced cases it will be best to give a general anesthetic and forcibly correct contractures. Tenotomy will be required in some cases.

If pain upon using the joint is severe, immobilization and protection by the splint which is used in tuberculosis of the joint may be applied. In connection with this, the local stimulating treatment is employed. Gradually the patient is required to give more and more use to the joint until the splint is discontinued. Insisting on use of the joint, even though pain is complained of, may rarely be required.

By filling the patient's mind with a desire to be well, by constantly suggesting improvement, by eliminating the neurotic cause, and by applying the local measures above described in such a manner as to suggest help and improvement, a cure can confidently be expected.

Irritable Spine

This condition, sometimes described as neurasthenic, hysterical, or sprained spine, is not a disease entity but represents several different disease conditions; and a successful treatment depends upon recognizing the cause of the irritability. Tuberculosis must be excluded.

Neuromimetic or hysterical spinal disease should receive the treatment above described.

Faulty or strained position, disturbing the normal balance of the spine, may be the cause and when this cause is removed and the balance of the spine restored by proper gymnastics or braces, the disease disappears. Inequality of the length of the legs, by inducing scoliosis, may be responsible. Here a cure is effected by a lift under the sole.

Flatfoot and other diseases of the lower extremities which disturb the normal suppleness of the limbs may throw a strain upon the spine sufficient to cause the disease, which persists until the causative factor is remedied.

Traumatisms and strains, causing local infiltration about the spinal nerve roots, may be the cause. In these cases rest is imperative. It is best secured by a jacket of plaster-of-Paris or other material such as is used in spinal caries (see Tuberculosis of the Spine, Vol. II). In severe cases even this will not suffice, and the patient must be treated in the recumbent position, fixed to a frame. Fatigue should be guarded against when these patients begin to go about.

The treatment of the slight subluxations of the spine has been described (see Dislocations of Vertebræ, page 620).

Many cases represent a combination of traumatism and neurasthenia or hysteria. The traumatism has produced some irritation of the region of the spinal nerve roots and the neurosis exaggerates and perpetuates the symptoms. Such patients should receive sympathetic consideration. A jacket or immobilizing splint should be used at first. This should be discontinued gradually, and followed by the local treatment advised for neuromimetic joints. Vibratory massage is of service here. A good method of treatment is to employ a removable jacket which will permit the daily use of local stimulating measures.

It is in this class of cases that quackery meets with its most striking successes.

Neuralgia of Joints

This rather vague condition of joint pain, not neurotic, hysterical, nor due to discoverable local lesion, often is traumatic, reflex, or of toxic origin. The cause should be discovered, if possible and removed. When no cause can be determined, the surgeon is always on the safe side in advising rest. If the pain is severe, immobilization is called for.

HEMOPHILIAC JOINTS

A person with hemophilia, who sustains a traumatism to a joint is prone to suffer from hemorrhage into the synovial sac. Such a condition must be differentiated from tuberculosis. Operation need but rarely be done. The condition is best treated by a protective and immobilizing splint, and constitutional attention to the blood disease (see Hemophilia, page 359).

JOINT MALPOSITIONS DUE TO CONTRACTURES OF THE SOFT PARTS

The treatment of distortions due to contractures of the soft parts is described in connection with the separate joints under the diseases of the extremities. There are certain general principles of treatment which apply to all joints which will be presented here.

In correcting these deformities, the elasticity of the soft parts should be kept in mind. It is a tissue peculiarity of much importance. A second peculiarity of the bony tissues is the tendency to atrophy under the influence

of pressure greater than normal and to hypertrophy when the pressure is less than normal. Thus if the knee-joint is pressed inward continuously for a long time, the result will be a change in the bony structure tending toward genu valgum. This is because such pressure causes the outer condyle to press more strongly upon the outer side of the tibia, while the pressure upon the inner side of the joint is less than normal. The result is that a bony hypertrophy of the inner condyle and an atrophy of the outer condyle take place. A similar change takes place in the head of the tibia. These

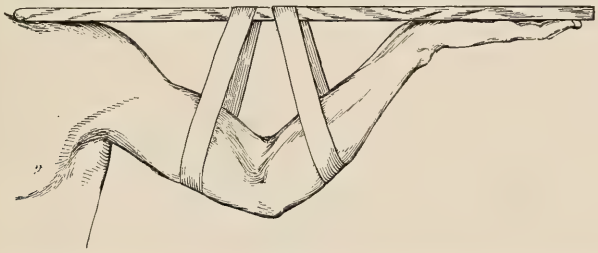


FIG. 493.—METHOD OF MAKING EXTENSION AT ELBOW BY ELASTIC PRESSURE.

changes, of course, are most pronounced in bones which are still growing, but they may take place at any age. Thus the correction of joint distortions may be accomplished by resorting to immediate stretching of the soft parts, and holding the joint in corrected position, or the slow process of stretching may be resorted to, combining or not the changes in the joint structures by virtue of increased or diminished pressure.

Joints which do not permit proper flexion or extension because of contractures of the soft parts may be treated by one of several methods. There is apt to be more or less ankylosis in these joints.

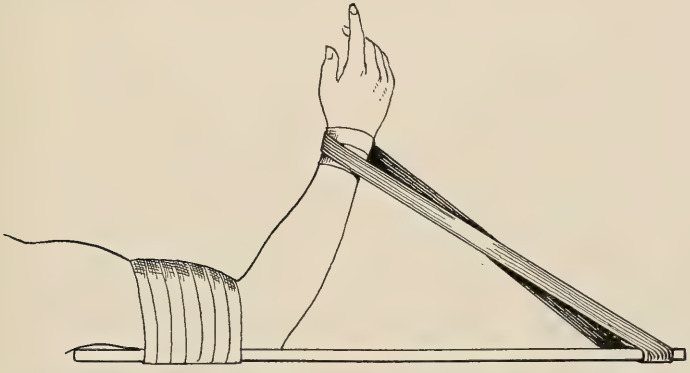


FIG. 494.—METHOD OF MAKING EXTENSION AT ELBOW BY ELASTIC TRACTION.

Gradual manual correction may be made as far as the patient can stand it without too great pain. Skin, fascia, connective tissue, muscles, and ligaments may thus be stretched. By combining this operation with massage of the stretched structures with oil or fat, the cure is hastened. Instead of massage, hyperemia, induced by heat, is of service. The stretching may be done once daily. If a painful reaction follows, as expressed by swelling, heat and pain, the operation should not be repeated until the reaction has subsided.

Rapid manual correction may be done at one sitting with or without general anesthetic. How far the surgeon may go in flexing or extending a limb must be a matter of judgment to be applied to the individual case. The danger of rupturing large blood-vessels, passing near the joint, must always be borne in mind. Pains should be taken to inflict the least possible traumatism. As few movements as possible should be employed to accomplish the desired result. Whatever is gained should be secured by the

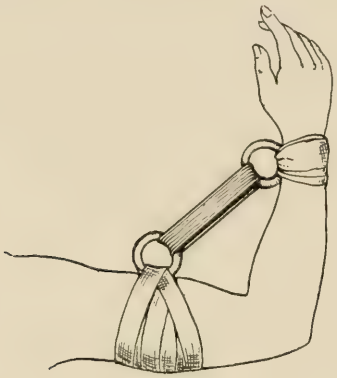


FIG. 495.—METHOD OF MAKING FLEXION AT ELBOW WITH ELASTIC BAND.

subsequent use of a splint until the traumatic reaction has subsided. Forcible and painful operations such as this should not be practised if internal ankylosis also is present.

Splints to secure correction are employed with advantage. A good plan is to make correction as far as possible, apply a light splint of plaster-of-Paris or other material, and allow a liberal lapse of time. The operation is repeated until the desired result is reached. The period of rest may vary

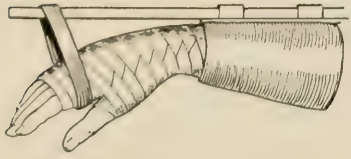


FIG. 496.—ELASTIC TRACTION APPLIED TO OVERCOME FLEXION CONTRACTION OF WRIST. (*After Hoffa.*)

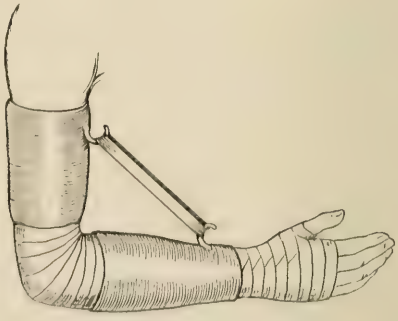


FIG. 497.—ELASTIC TRACTION TO OVERCOME EXTENSION CONTRACTION OF ELBOW (*After Hoffa.*)

from a day to one or two weeks. Another method is to apply a plaster-of-Paris bandage, make the correction while the bandage is soft, and hold the parts corrected until the plaster becomes hard.

Traction by weights is of service, and is employed much as in the treatment of fractures. Various lines of traction may be applied. The weights should not be so great as to make the patient uncomfortable (see Traction in the Treatment of Fractures).

Elastic traction is used in connection with splints or adhesive plaster. Coiled springs, straight springs, or rubber elastic is employed. The general principles of this method are shown in the accompanying illustrations.

In using elastic traction, rubber elastic is the best material. Care should be taken to prevent pressure necrosis. This may be prevented by proper padding. Joints in the flexed position which require to be moved toward extension may be treated by a long splint on the flexor side and an elastic band acting between the joint and the splint (Fig. 493). Or a long splint

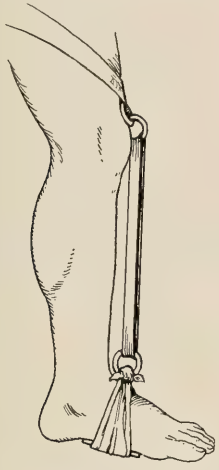


FIG. 498.—ELASTIC TRACTION TO OVERCOME EXTENSOR CONTRACTION OF ANKLE.

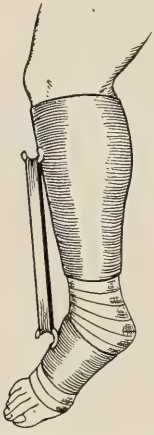


FIG. 499.—ELASTIC TRACTION TO OVERCOME EXTENSION AND INVERSION OF FOOT. (*After Hoffa.*)

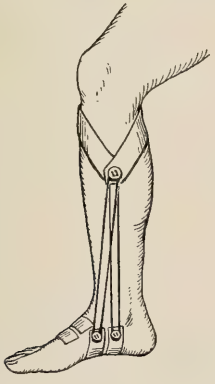


FIG. 500.—ELASTIC TRACTION TO OVERCOME EVERSION OF FOOT.

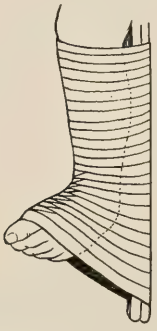


FIG. 501.—BANDAGE TRACTION FOR INVERSION OF FOOT. (*After Hoffa.*)

may be extended beyond the joint and the elastic carried from the lower part of the limb to the end of the splint (Fig. 494). For flexing a joint the elastic may be carried between the ends of the two arms of the angle of which the joint forms the apex (Fig. 495). The natural ingenuity of the surgeon is the important element in the treatment.

In the cases of the knee and the hip, the weight of the limb may be used to effect either flexion or extension. A knee which requires to be flexed may be allowed to hang over the edge of a support as the patient lies or sits, the weight of the leg gradually causing flexion. Other expedients are shown (Figs. 496, 497, 498, 499, 500 and 501).

Artificial hyperemia, applied by means of vacuum or suction apparatus, is easily combined with gradual correction, and has a decided effect in increasing the movement of contractured joints. Under the influence of the active hyperemia the stretching of the soft tissues seems to be facilitated. The Bier apparatus is applicable to the joints of the extremities (see Artificial Hyperemia).

Operative correction is called for in extreme cases, in cases in which time cannot be given to the other methods, and in cases in which the contractures are old or are associated with much scar tissue. The operations which are of service are divisions of the soft parts, and operations upon the bones.

When *division of the skin* is required for contraction, the operation should be done in such a way as to leave the smallest possible wound. If it is feasible the wound should be that of a plastic operation which can be closed by sutures (see Plastic Surgery). Usually a V-shaped incision permits this. The same principle holds true of *division of fascia.* If the contractured fascia is an important structure, as the plantar fascia, it should be lengthened by plastic incision but not completely divided and separated. *Tenotomy* is one of the most common operations practised for this condition: it is described elsewhere. *Division of muscle* becomes necessary occasionally in extreme cases.

RELAXED KNEE-JOINT

This condition, which occurs in children usually between three and six years of age, who have grown fast, and are fat and flabby, is often characterized by knock-knees, and requires attention to the general hygiene before local treatment can be applied to advantage. Massage of the muscles of the leg and thigh and of the knee region is valuable. Healthful outdoor exercises, to improve the general health and strengthen the leg muscles are useful. Apparatus should not be used for the knock-knee unless it is pronounced. For the eversion of the foot the inner side of the heel and sole of the foot should be elevated by adding a wedge 5 or 6 mm. ($\frac{3}{16}$ or $\frac{1}{4}$ inch) thick. The hyperextension of the knee is best counteracted by adding a heel to the shoe so as to throw the body forward and cause the child to stand with the knee slightly flexed. If the ligaments of the outer side of the knee are so shortened as to prevent straightening of the limb, these ligaments should be stretched by manual force several times daily. This force should be stopped just short of causing the child pain.

ANKYLOSIS

Ankylosis of the several joints is discussed under the diseases of the extremities. There are certain general principles of treatment which will here be described. Before treatment is begun, it must be determined whether the ankylosis is due to soft adhesions or to actual bony union between the elements of the joint. The *x*-ray will often be required to decide. If the ankylosis is not bony, the adhesions may often be broken up, and the resulting raw surfaces become covered with synovial tissue.

An acutely inflamed or painful joint should not be moved. Passive motion, forcible flexion and extension, and breaking of adhesions should not be applied when they cause pain or require an anesthetic for their application. A joint should be kept quiet until pain and inflammation have gone. Then it should be moved only so far as is possible without producing pain. The natural uses of the joint are best. Passive motion and massage may be applied, but they never should cause pain. All motions should stop short

of causing pain. Pain is the natural protector of joints. It throws the muscles into a state of tension, which fixes the joint and prevents motion.

Soft adhesions may be broken by moving the joint in one direction and then in the other direction as far as is possible without pain. This should be done with little manipulation lest too much traumatic reaction be excited and more adhesions formed. After thus moving the joint, a splint should be applied, and rest insured for at least twenty-four hours. The operation should be repeated every day or two.

Forcible means may be employed, as are described above in the treatment of contractured joints, when the stiffness is not due to internal adhesions. By this method the adhesions outside of the joint are stretched and broken by strong force applied to the anesthetized patient. The joint is then fixed in a splint to insure quiet; and, if necessary, the operation is repeated after several days when the traumatic reaction has subsided.

The use of artificial hyperemia is of much service in increasing the elasticity of the adhesions and in hastening the healing of the wounds caused by their rupture. This is secured by means of the elastic band, vacuum apparatus, passive congestion, hot air, hot packs, vibratory massage, etc.

Operative treatment is called for when the adhesions cannot be broken up or when the ankylosis is bony in character.

Arthroplasty, for the creation of a joint by interposing soft tissues between the bones, is the most satisfactory operation for ankylosis (see Operation on Joints, page 757).

Osteotomy, just above or below the joint to correct vicious position, gives corrected position but still a stiff joint. When arthroplasty is not elected osteotomy is of service (see Osteotomy, page 711).

Excision of joints which are the seat of bony ankylosis is done to secure better position. Osteotomy gives angulation at the site of section, but excision is carried out in such a way that the desired position is secured by placing the bony planes in apposition. It has the disadvantage that it gives no motion and some shortening.

OPERATIONS ON BONES AND JOINTS

Bony tissue is made up of two-thirds earthy matter, which surgically is comparable to a foreign body. So long as there is no infection, this large amount of inorganic matter lies in normal relation with the organic cells, but when infection of bone with irritating bacteria takes place, the earthy material becomes obnoxious foreign matter, acting as a harbor for infecting organisms, into which the phagocytes with difficulty penetrate, and provoking irritation by its mechanical presence. The tendency of the inflammation is to continue until the necrotic bone has become broken down and absorbed or exfoliated in mass or in solution. Because of the meager resisting power against infection possessed by bone, and because of the prolonged destructive process which is started by infection, care to guard against it is imperative.

In the long bones the vitality of the bone depends upon its relation to the periosteum and marrow. These two structures should be respected. In young persons the periosteum will regenerate new bone, and this property often may be used to the great advantage of the patient.

The involucrum, or deposit of new bone which springs up from the periosteum about the necrotic sequestrum, is at first poor in earthy material and, therefore, very pliable and easily broken.

The operation of **elevating** the **periosteum,** with the view of saving it, is worthy of special consideration. It is important that the operation be begun right. This requires that the periosteum should be cleanly and strongly incised; a sharp-edged elevator (not a blunt instrument) should be used; the elevator should be kept close to the bone, working its way under the periosteum, which should be elevated untorn, carrying with it some of the bone, if necessary. It should not be scraped off and torn into shreds. At points where it is particularly desirable to preserve the periosteum or the muscular attachment into the periosteum, a thin shell of bone may be chiseled off. In the excision or curetting out of carious bones the interior of the bone may often be wholly removed and the periosteal shell left. This should be done whenever practicable.

In operating for acute inflammation in bone a point of tenderness can often be discovered before the patient is anesthetized, and this will represent the location of the disease. A sand-bag should be interposed between the soft parts and the table when bone is chiseled, to take up the jar of the mallet and prevent traumatism to the opposite side of the limb. The hand-saw or the circular-saw, driven by electric power is to be preferred to the chisel. Drills, burrs and trephines also are driven by electric power. These engines in skilled hands are to be preferred to muscular power. The surgeon should have well in mind the anatomy of the structures lying in relation to the bone, and also the location of the epiphyseal lines in the young.

The **instruments** used in exposing and cutting bone should be simple and strong (Figs. 502 and 503). Special instruments will be found described also in chapters on fractures and operations on the skull. The electric motor is particularly useful in bone grafting and bone plastic operations (Fig. 504).

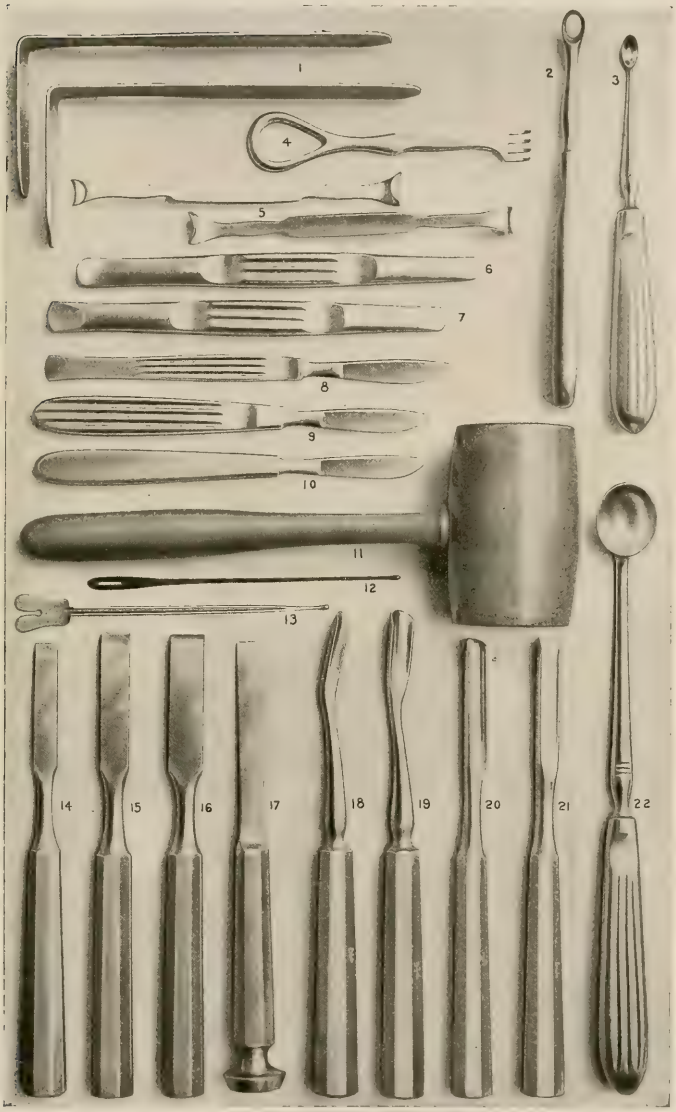


FIG. 502.—INSTRUMENTS EMPLOYED IN OPERATIONS ON BONES AND JOINTS.

1, Flat retractors; 2, 3, and 22, curets; 4, hook retractors; 5, round retractors; 6, periosteal elevator; 7, periosteotome; 8, 9, and 10, knives; 11, mallet; 12 and 13, probes; 14, 15, and 16, chisels; 17, osteotome; 18, 19, 20, and 21, gouges.

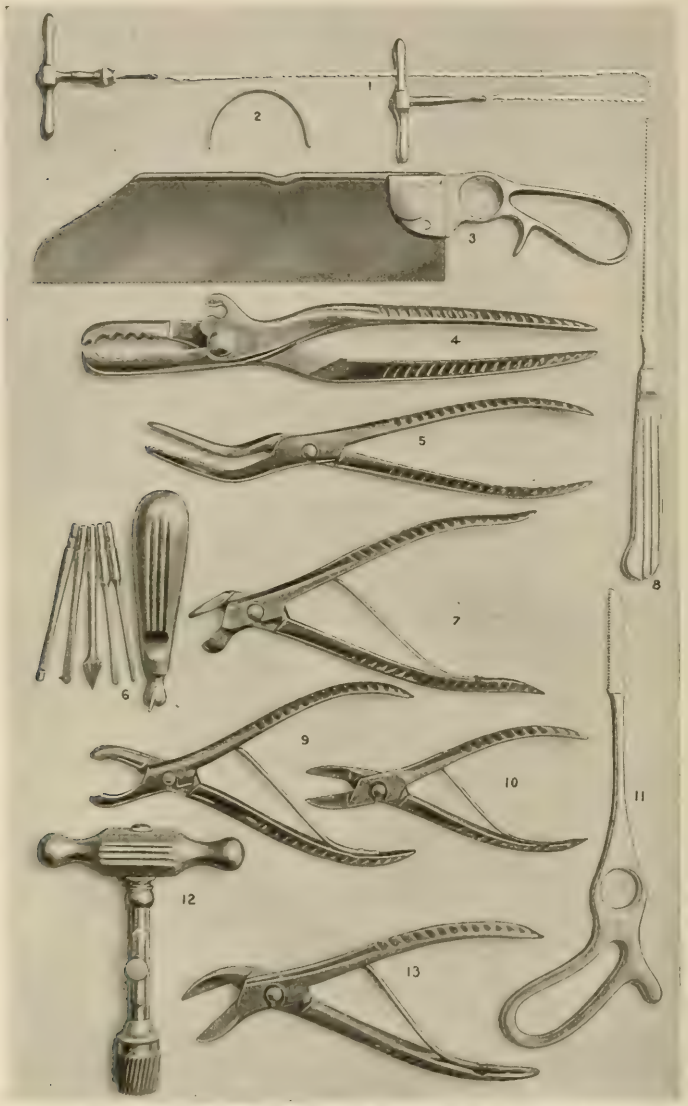


FIG. 503.—INSTRUMENTS EMPLOYED IN OPERATIONS ON BONES AND JOINTS.

1, Chain-saw; 2, chain-saw carrier; 3, flat saw; 4, lion-jaw forceps; 5, sequestrum forceps; 6, bone drills; 7, bone-gouging forceps; 8, metacarpal saw; 9, bone-gouging (rongeur) forceps; 10, straight bone-cutting forceps; 11, Adams' saw; 12, trephine; 13, angular bone-cutting forceps. Not shown: Scissors, hemostats, needles, wire, suture materials, anatomic forceps, toothed forceps, mouth-gag, tracheotomy tube, bone-nails, Gigli saw, sponge-holders, and dental forceps.

While hand chisels and saws may be used for *cutting grafts of bone*, the most effective instrument is the electric motor. A small universal motor is made which is enclosed in a sterilizable case, and may be held in the hand. The current is controlled by a foot switch. Saws and drills of various shapes may be used with this apparatus. The double circular saw permits cutting parallel lines in bone. The spiral osteotome cuts a line and is used in craniotomy and laminotomy. A spray and guard is used with some instruments to keep a constant stream of saline solution flowing on the saw to prevent

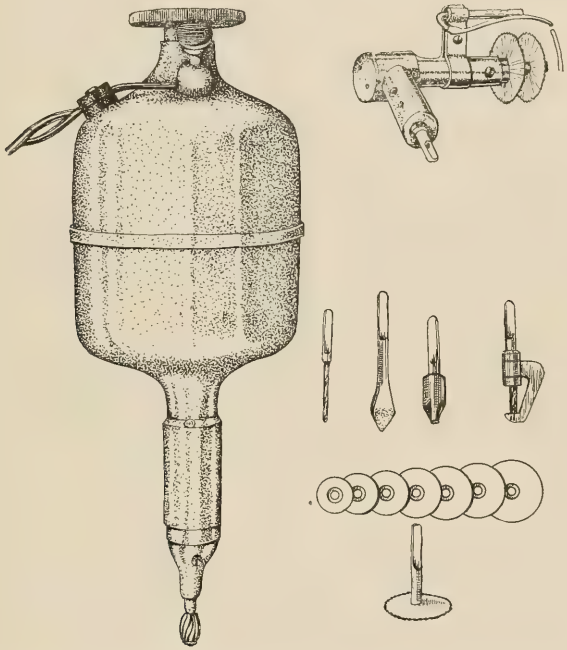


FIG. 504.—ELECTRIC MOTOR WITH STERILIZABLE COVER.

Drills, burrs, trephines and circular saws may be used with this motor. The double saw for cutting parallel lines for bone-grafting is shown at the upper right aspect of the picture. This is operated by the electric motor through the right-angle attachment. Note tube to connect with water pipe to play a stream of water on the saws when in operation. The washers arranged above the bottom circular saw are to regulate the depth to which the saw shall cut.

heating of the bone. Other motors may be adjusted to run slowly so as to develop little heat. The saw of Doyen is an ordinary circular saw provided with a series of washers of various sizes which regulate the depth which the saw may cut (Fig. 504). Each washer is stamped with a number which shows the depth in millimeters the saw will cut when the given washer is used. The number is simply one-half of the difference between the diameter of the saw and the diameter of the washer.

While typical operations are described, the performance of such operations is not to be aimed at. The surgeon should treat each case according to its peculiarities. Modern therapeutic measures are greatly reducing the necessity of mutilating operations upon joints and bones. When sinuses exist, which it is desirable to follow up to their origin, methylene-blue solution injected into the lumen produces a deep blue stain of the sinus wall, which

enables the surgeon to follow it during the progress of the operation; a bismuth-vaselin paste also will show the sinus in a skiagraph. After operations on bones of the extremities it is well to elevate the part in order to minimize congestion and pain. Suture of bone is accomplished by means of chromicized catgut, kangaroo tendon, bronze wire and silver wire. Nails, pegs, screws, dowels, plates, rings and the ordinary suture materials are also used.

FIG. 504*a*.—SURGICAL ELECTRIC MOTOR.

This motor is covered with a casing which is removable and sterilizable. The handle gives the operator control of the instrument and prevents its rotation. The motor is here shown fitted with a burr.

OPERATIONS FOR PERIOSTITIS, OSTEITIS, OSTEOMYELITIS, AND LOSS OF BONE SUBSTANCE

Periostitis.—Periostitis, with elevation of the periosteum by infective products, requires incision, which should be made parallel with the long axis of the bone. This incision should be made usually over the point of greatest tenderness, and should supply free drainage.

Osteomyelitis.—*Operation in the acute stage of osteomyelitis*, during the first forty-eight hours, is the operation of choice and should be practised whenever possible. If operation can be done at this early stage, the extensive destruction of bone which so commonly results from this disease can be

averted. The limb should be emptied of blood by elevation, and the elastic bandage applied, jumping over the diseased region without compressing it, and the hemostatic constriction made well above the seat of disease. If the disease is still confined to the medulla, the surgeon should be guided by the pain in selecting the place to open the bone. A small painful area will usually be found by making pressure on the bone. A longitudinal incision

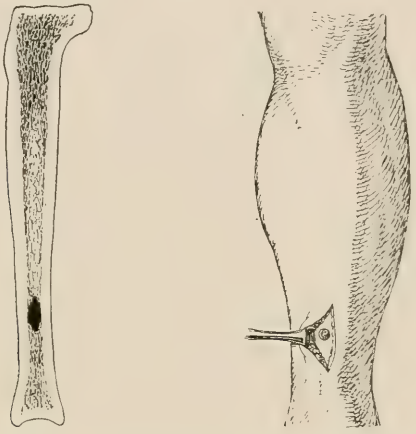


FIG. 505.—EARLY OPERATION FOR ACUTE OSTEOMYELITIS.

Note simple incision and trephine opening of medullary space. This is all that is required in first thirty-six hours. The disease is still localized. The patient may be expected to recover without further complications.

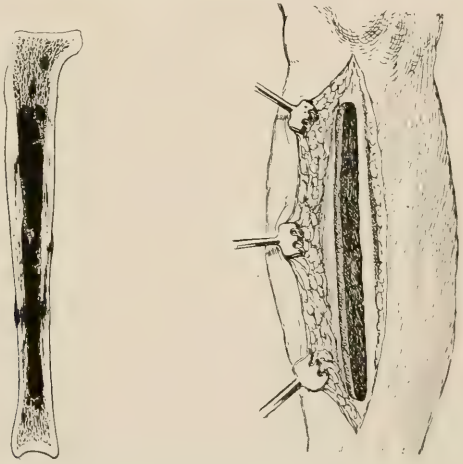


FIG. 506.—OPERATION FOR ACUTE OSTEOMYELITIS A FEW DAYS LATER.

The shaft has been destroyed by the disease, the leg is edematous and infiltrated with inflammatory products, metastases are present in other bones, an infected clot has formed in the heart—all this while the patient was being treated with poultices, internal medication and vaccines. Recovery is doubtful.

should be made, the soft tissues and periosteum retracted, and the bone trephined at this place. The medulla will be found infiltrated with pus. All that is required in this condition is to insert a drain in the opening, close the rest of the wound, and apply a copious dressing (Fig. 505).

If periostitis has developed, the bone should be exposed at that point. The periosteum should be incised to the full extent of its inflammation. It should carefully be stripped up from the bone, held apart by retractors, and the bone examined for openings through which pus is escaping from the marrow cavity. If an opening is found, the trephine or chisel should be applied at this place and the medullary cavity opened. If no fistulous opening is discovered, the medullary cavity should be opened at the most convenient point in the wound

When operation is done early enough the medulla will be found inflamed and infiltrated with pus, but not destroyed. This inflamed medulla should not be curetted or disturbed. The simple opening for drainage of the bone canal should suffice to check the progress of the disease; and the earlier this operation is performed the less will be the subsequent destruction of bone. Upon opening the canal, however, if broken down and disintegrated medulla is discovered, or if the medulla is found to be displaced by pus, the bone covering this area should be removed with the chisel up to the point where simply inflamed, but not disintegrated, medulla is found (Fig. 506). The old practice of curetting out inflamed medulla can not be condemned too strongly. The disease is a cellulitis, and the object of operation should be to save as much tissue as possible. Free drainage, just as in cellulitis in other tissues, and not the removal of the inflamed structures, is the important thing. This medullary tissue plays too important a rôle in the economy of the bone to be sacrificed. Its friability and the ease with which it can be removed are no criteria of its importance. It should always be borne in mind that the vitality of the bone depends upon the periosteum and the medulla, and that the bone does not perish until these become separated from it. All operations for osteomyelitis should aim to preserve these two tissues, and to do so the surgeon may sacrifice as much bone as is necessary. Inflammatory products, confined under the pressure of the unyielding bone, rapidly destroy the medulla; and under the periosteum, until evacuated, they rapidly strip it up from the bone. The cavity of the bone having been opened, a rubber drainage-tube or a very loose capillary drain is inserted through the soft tissues down to the bone, and the wound left open or, if a large excavation of bone has been made, the cavity should be packed with gauze, partially closed by suture, and covered with a copious, moist, absorbent dressing.

Operation for this disease may be done in two stages: the first for drainage of the medulla, as soon as the diagnosis is made; the second during the subacute stage, for the removal of necrotic bone. If the first is done early enough, the second will not be necessary. There are few operations in surgery in which prompt action is more imperative. The infection is developing in unyielding tissue; the swelling of inflammation cannot be accommodated; occlusion of vessels with infected clots, necrosis of bone and metastatic infections result unless prompt relief is secured. This is the disease which is so commonly diagnosed as "rheumatism," arthritis, and later as erysipelas, abscess, or typhoid, and denied the prompt treatment which would prevent metastatic abscesses, and infective embolism. There is no single disease which is a greater reproach to the medical profession. The tardiness of the general practitioner to secure prompt relief in acute osteomyelitis is inexcusable. The recognition of the disease is easy, the treatment is simple. Operation at the hands of the most unskillful is not so dangerous as the disease when left unoperated upon. Many children are crippled and die of this disease; and yet in a surgical experience of twenty-five years, I have rarely

known a general practitioner to recognize acute osteomyelitis in its first stage, and secure immediate surgical relief without wasting precious time with palliative measures while the bone destruction and general infection progressed. This is the odium of medicine (J. P. Warbasse: "The Physician's Responsibility in Acute Osteomyelitis," Jour. Am. Med. Assoc., Apr. 17, 1915).

Operation in the subacute stage of osteomyelitis, after spontaneous evacuation of the medullary pus has taken place, and destruction of bone has come to an end, provided there is free drainage and no retention, is performed to the best advantage usually about two months after the acute onset. This can be done in the case of bones having a parallel fellow to act as a splint. At this time new bone is well advanced in development from the periosteum, where it has become separated from the old bone; a sequestrum may be present; and, if the death of bone has been extensive, demarcation is well defined. Ischemia should be produced with the rubber bandage. The soft parts and the periosteum should be divided down to the necrotic bone. It is well to make the incision near the sinus opening, or to follow the old line of incision if the operation is a secondary one. The periosteum, the inner surface of which will be found covered with new bone, should be elevated whole from as much of the shaft as is necrotic. It should be retracted with the soft tissues, and the naked bone exposed. Any sequestra which are present should be lifted out, and the dead bone which is still attached should be removed. It will be observed that the dead bone is pale in color, does not bleed when cut, and is separated from its periosteum. In the case of the long bones this is best removed with the chisel and mallet. The operation should be carried in each direction until healthy bone is reached. Living bone is recognized by the presence of minute bleeding points, representing the divided blood channels. The surgeon should not expect free hemorrhage from the bone, he should stop at the first evidences of vitality, bearing in mind that the bandage constriction minimizes the show of blood. If the whole diaphysis is necrotic and is removed, profuse hemorrhage often takes place from the interior of the involucral shell. This is best controlled by packing with iodized gauze.

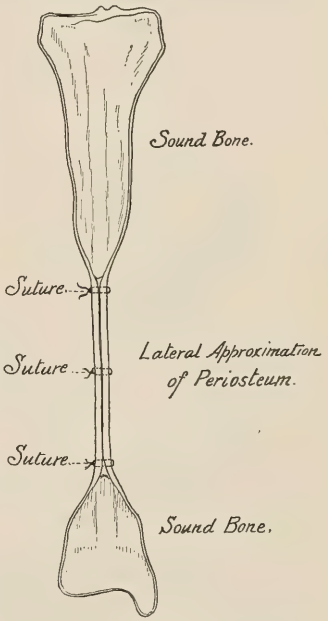


FIG. 506*a*.—TREATMENT OF OSTEOMYELITIS IN THE SUBACUTE STAGE. (*After Nichols.*)

Showing middle segment of bone removed, healthy bone ends made wedge shaped, and periosteum laterally approximated.

As an operation of preference in osteomyelitis of the tibia it is possible to proceed as follows: The healthy remaining bone above and below is beveled so as to end in a wedge, unless the epiphyseal line renders it impossible. The periosteal new bone casing, after the removal of the dead shaft, is disinfected with phenol or chlorin solution. This tube of periosteum is then caused to collapse, and its cavity obliterated by holding the opposed surfaces together with a few interrupted sutures of chromic gut. The soft parts are then loosely closed with some provision for drainage (Fig. 506*a*). This is the method of E. H. Nichols.

In the case of the femur and humerus this operation cannot be done to good advantage. In these bones it is well to leave the diaphysis until the new periosteal bone has become strong enough to support the limb. Often, however, a radical operation may be done and the fragile bone-shell preserved by applying the same splint apparatus as would be employed in the treatment of a fracture of the particular bone. The best results are secured in the case of either of these bones, if the whole diaphysis is necrotic, by freely exposing it and laying open the medullary canal or chiseling fenestra into it at frequent intervals. This gives drainage, and the sequestrum remains as a splint until the involucrum has become sufficiently strong.

This subacute stage is understood to be the stage in which the periosteum and its new bone are not yet strong enough to support the limb. If the surgeon can secure a piece of bone from an amputated limb, an osteoplastic operation may be attempted; but the possibility of failure is so great that the living or the patient should not be called upon to furnish the bone. The dead bone should be removed, and the cavity enclosed by periosteum should be sponged dry and sterilized with 3 to 10 per cent. iodin solution in alcohol or with phenol, followed by alcohol. A piece of bone, taken from the tibia or fibula, should be inserted in the cavity which has been prepared to receive it, as for bone grafting. The skin should have been sterilized with iodin, and sinuses should have been excised. The wound should be sutured throughout and the limb put up as a fracture.

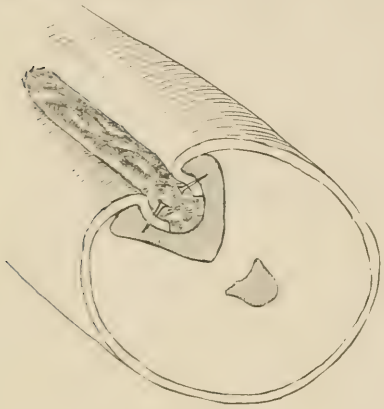


FIG. 507.—OPERATION FOR OSTEOMYELITIS.

Skin turned into bone cavity, and held by nails and gauze, after the cavity has been uncovered.

Operation in the chronic stage of osteomyelitis is done when the necrotic shaft is broken down, the new periosteal bone is thick enough to support the limb, and often hard and eburnated, and when there may be present dense deposits of endosteal bone. It is in this stage that operation is usually performed, and to this the term "sequestrotomy" belongs. It was formerly the custom to expose the bone at the sinuses, enlarge the opening sufficiently to remove the sequestrum, scrape out the cavity, and pack it with iodoform gauze. In the case of very small bone cavities this method is still the best. In the large cavities, however, on account of the great slowness with which the new periosteal bone or involucrum grows into the defect from which the sequestrum was removed, and on account of the fact that by this method small sinuses leading to other sequestra are apt to be overlooked, giving rise to long-continued suppuration and often requiring subsequent operations, the old method has been supplanted by more radical measures. These measures for healing the defect in the bone, resulting from the disease and from the operative removal of the dead bone, may be described under the following headings: (1) Autoplastic Operations with Soft tissue; (2) Autoplastic Operations with Bone; (3) Bone-grafting and Transplantation; (4) Aseptic Bone-cavity Filling.

The ingenuity of surgeons has devised many methods of treatment, but only the most important will be described. Each case is peculiar. Practical familiarity with the principles of surgery is essential for success. These

operations are all done to the best advantage with the limb rendered ischemic by the rubber elastic bandage. It should be understood that there is no sharp dividing line between the subacute and chronic stage of the disease, and any of these procedures may be applied in the former, provided the limb is supported so that the involucrum is kept immovable during the healing process.

Autoplastic Operations with Soft Tissue.—The bone cavity should be completely unroofed; that is, the involucrum should be cut away with chisel and rongeur throughout the whole length of the cavity on the wound side of the bone, to such an extent that the remaining trough represents nowhere more than half a circle. This bone trough should be thoroughly scraped out with the curette. Sharp and rough edges of bone should be removed because of the tendency of projecting points to fall into decay. A search should be made for other sinuses, especially small ones. These should be laid open freely. It will often be found that such sinuses lead out to the opposite side of the bone and end under the soft tissues. Invariably a periosteitis has existed at such places and often a superficial sequestrum will be discovered. It is well at such points to lay open the soft tissues to the surface, and introduce a drainage-tube down to the bone, after having removed any dead bone which may be present. Very commonly, however, these places heal without making the additional opening through the soft tissues.

The cavity should now be sterilized by means of pure phenol applied for two minutes, followed by alcohol, and then a washing out with salt solution. There are other measures for rendering bone cavities aseptic which the choice of the surgeon or the circumstances of the case may prompt him to adopt. Filling the cavity with olive oil and raising the oil to a temperature of 100°C. (212°F.) by the thermocautery; conducting live steam by a rubber tube into the bone, the surrounding tissues being well protected by cold wet compresses; filling the cavity or swabbing it out with tincture of iodin, if it is not too large, and washing this out immediately with alcohol; irrigation with formaldehyd and other antiseptic solutions—all of these methods have proved efficient. It should always be borne in mind that treatment such as this, while it destroys bacteria, also leaves a layer of devitalized tissue lining the wound, and if it is desired that transposed living tissue shall grow adherent to the wound surface, it is best to defer the transposition until it can be made against aseptic granulations. Therefore, after such sterilizations, the best success is secured by packing the cavity with gauze and awaiting the development of a layer of granulation tissue. By this means a layer of vascular soft tissue is secured, and an opportunity is afforded for the elimination of necrotic particles. If the cavity with the whole leg is kept dressed under scrupulous conditions with copious wet salt solution or borosalicylic dressings, clean granulations will be secured, which will require no further chemical treatment.

After granulations have appeared, before proceeding with a plastic operation, the cavity should be washed out with salt solution; but the granulations should not be traumatized nor made to bleed with either sponges or instruments. The surgeon may then proceed to cover these granulations by flaps of skin turned in from the neighboring surfaces, or by skin-grafts. If neighboring attached skin is simply turned down into the bone excavation, the operation may usually be completed successfully at the first stage; but if grafts or skin, swung about upon a pedicle, are employed, the presence of healthy granulations adds much to the insurance of success.

If the bone cavity is not deep and the surrounding skin is in good condition, the skin may be dissected up on either side for the length of the wound and simply turned down into the bone trough. It may be held here by bone-nails and a light gauze packing (Fig. 507). Mattress sutures are also of service (Fig. 508). Pediculate flaps may be turned in and held in place in the same manner. In cases in which there is a large cavity it is wise not

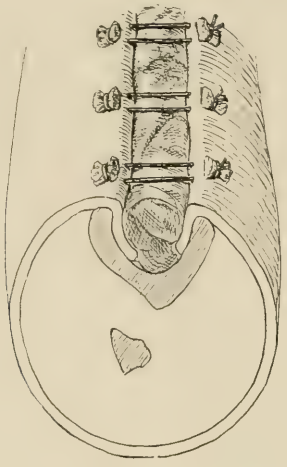


FIG. 508.—OPERATION FOR OSTEOMYELITIS.
Skin turned into bone cavity, and held by bolster sutures and gauze.

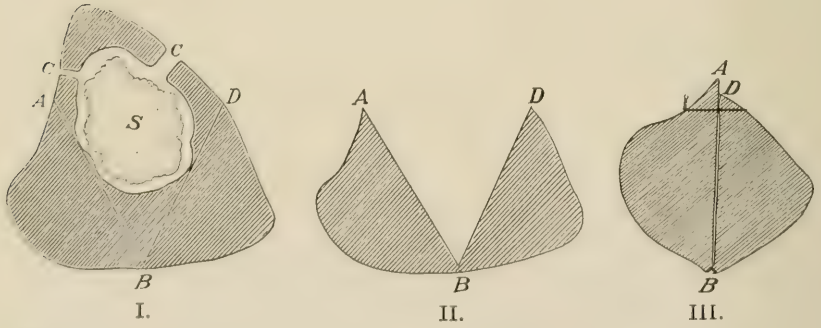


FIG. 509.—LONGITUDINAL FRACTURE METHOD OF OBLITERATING BONE CAVITY.
I. *S*, Sequestrum; *C*, cloaca; *AB*, *BD*, planes to be cut. II. Showing cleaned out involucrum. III. Involucrum fractured longitudinally, closed up, and wired.

to attempt too much at one sitting. The plastic operations may be done to advantage at intervals. Flaps for this purpose may be taken from the other leg when no other skin is available.

Autoplastic Operations with Bone.—The operation is proceeded with as above, except that as little of the new bone as possible is removed, only enough for the removal of sequestra and the cleansing of the cavities. The best results are procured here also by operating in two stages, although immediate completion of the operation may successfully be done in one stage. One or both sides of the involucrum may be separated above, below, and longitudinally by the saw and chisel, and turned into the cavity. This

is essentially the construction of a flap of soft parts and bone. By such an operation the sides of the involucrum may be made to collapse and obliterate the bone cavity (Fig. 509). It is the most satisfactory of all the osteoplastic methods. Bier has described an operation whereby all of the involucrum is saved. By this method the cavity is uncovered by marking out a quadrilateral flap, corresponding in length with the length of the cavity. The soft tissues are incised, and in the same lines the bone is divided with chisel and saw. A skin-periosteum-bone flap is elevated as a valve, the cavity of the bone cleaned out and sterilized, and the flap sutured back in place (Figs. 510 and 511). The cavity fills with clot, which becomes organized and penetrated by osteoblasts. The success of this operation depends upon its asepticity; and the difficulty of rendering these wounds with sinuses

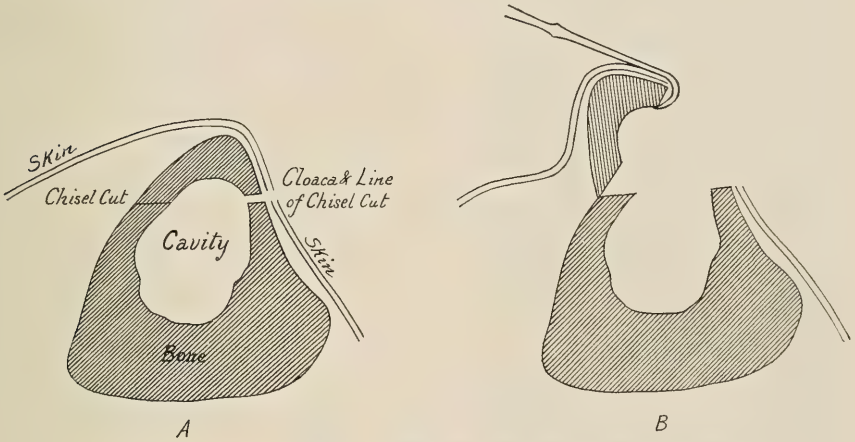


FIG. 510.—BONE-FLAP METHOD OF TREATING BONE CAVITIES.
A, Lines of division; *B*, flap held back with retractor and cavity exposed.

clean at one sitting demands that the operation be done in two stages. If this modification is applied, it becomes an ideal procedure, although it is applicable to comparatively few cases.

The ideal autoplastic operations with bone are done with bone taken from the patient's sound tibia. (See Osteoplastic Operations, pages 701 and 772.)

Defects Filled with Living Bone-flaps.—Autoplastic flaps are most successful. By this operation living bone is transplanted, with its vital connections not divided, to fill the defect in another bone. The operation in which detached fragments of bone are employed cannot properly be described under this head. The general principles of surgery and the ingenuity of the surgeon are called upon to solve each problem separately.

Operations for Loss of Bone Substance.—For loss of substance following either disease or injury, any of the above bone-filling methods may be used. Small gaps in bone may be filled by taking a small fragment from the adjacent bone-ends (Fig. 512). For filling the gap in old ununited fracture, or following osteomyelitis, a flap of bone, may be swung in attached to a flap of soft tissue (Figs. 513, 514, 515, and 516). These are the operations of Mueller, described in "Binnie's Operative Surgery."

Defects of the tibia may be filled by dividing the fibula and turning it into the defect. This may be done at one end of the defect or at both ends

(Figs. 517 and 518). The operation may be done in one stage or in two stages. The tibia may be made to rest upon the shaft of the transposed fibula (Fig. 519). Successful results are also secured by using only part of the thickness of the fibula (Fig. 520). These bone-flaps, if left attached to the adjacent fascia, are somewhat insured against necrosis. In the case of the tibia and fibula, the defect in the tibia is exposed by retracting outward the tibialis anticus muscle with the anterior vessels and nerve, freeing them from the anterior surface of the interosseous membrane, and carrying inward the flap of fibula attached to the membrane and adjacent muscle. Cases operated upon by the above methods show a surprising growth of the transposed bone. A segment of fibula, introduced into a tibial defect, unites as a fracture, and in the course of a year or so it will be found enlarged to the size of the tibia. The loss of the fibula does not seem to impair the function of the leg (Fig. 521). Whatever operation is done, the full weight of the body cannot well be borne on either tibio-fibular joint alone. Cases in which the fibula has been cut across, and the upper end of the lower fibular fragment placed against the upper tibial fragment, develop inversion of the foot which must be remedied by dividing the fibula lower down and planting it against the lower segment of the tibia (Fig. 519). The weight of the body must fall through the two extremities of the tibia.

Fig. 511.—Osteoplastic Resection of Involucrum.

Flap turned back and cavity cleaned out.

By leaving the transposed bone attached to a pedicle of fascia and muscle, the patella may be used to fill a defect in the tibia, the spine of the scapula may be introduced in a defect of the humerus, and any adjacent bone may be used in whole or in part for this purpose. (For further discussion see Bone-grafting and Transplantation, below.

An effective operation for *covering defects of the skull* is by sliding over it a sufficient area of the outer table of the skull, still covered with its periosteum and scalp, the whole operation being done through parallel incisions and without pedunculating the movable flap.

Heteroplastic flaps are taken from another person or animal. This method has been quite superseded by other procedures, but may rarely be found necessary. The bony defect is prepared as for an autoplastic flap, but the bone connected by a flap is transposed by fixing the limb of the supplying person or animal to the part to be repaired. The leg of one person supplying a piece of fibula or tibia may be made fast to that of the patient. The bone to be transferred is cut out but left attached to muscle fascia, and skin, to

insure its nourishment, and fitted into the defect. The two limbs are bound together by plaster-of-Paris or fixation apparatus. Human beings, dogs and other animals have thus been used successfully to furnish such grafts. The operation and after-care are difficult. The modern method of bone transplantation is infinitely more easy, and quite as certain of success in most cases.

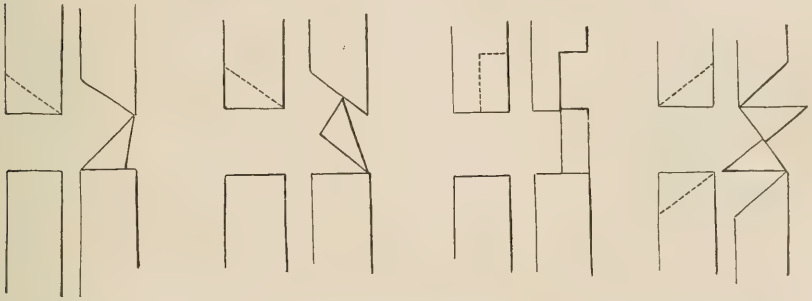


FIG. 512.—DIAGRAMS SHOWING METHODS OF LENGTHENING BONE FOR FILLING DEFECTS BETWEEN BONES.

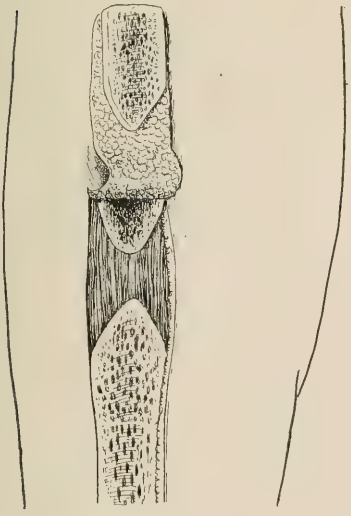


FIG. 513.

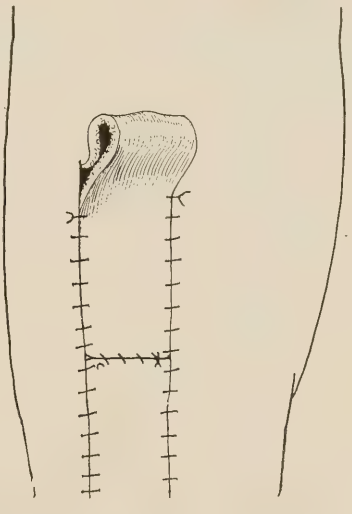


FIG. 514.

FIGS. 513 AND 514.—SLIDING FLAP OF SKIN, FASCIA, PERIOSTEUM AND BONE TO BE PLACED IN BONY DEFECT.

Such a flap, carrying a piece of bone may be used to bridge a gap caused by loss of bone due to fracture or osteomyelitis. The flap is placed in position in such a manner that the bone bridges the gap, where it becomes attached and in time hypertrophied. A sliding flap of skin closes the skin defect. (Fig. 513 illustrates Mueller's operation after Binnie.)

Bone-cavity Filling.—*Aseptic bone-cavity filling* is applied to cavities which are the result of injury, aseptic operation, or tuberculosis, to osteomyelitic cavities which have previously been cleansed and become lined with clean granulations, and to cavities which can be sterilized by the methods described above under *autoplastic operations with soft tissue*. The operation is not applicable to acute infective or suppurative cases. Many methods for the

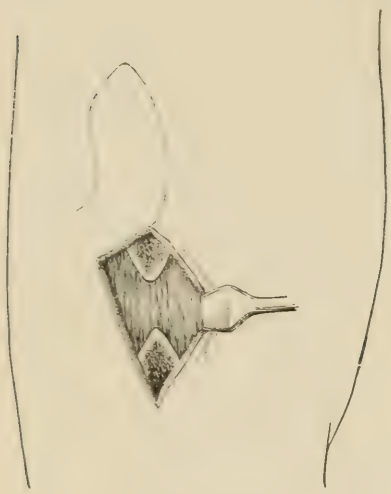


Fig. 515.

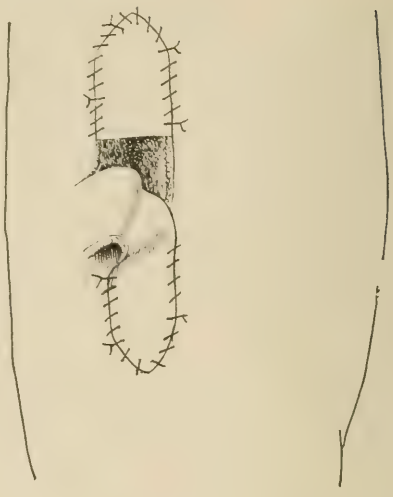


Fig. 516.

Figs. 515 and 516.—Operation for Swinging an Osteogenetic Flap, Consisting of Bone and Soft Tissue, to Connect the Fragments in Old Ununited Fracture and after Loss of Bone from Osteomyelitis.

The flap is liberated with a piece of bone attached to its posterior surface. The soft tissue cut from the area into which the osteoplastic flap is to be placed is transplanted into the area from which the flap is taken. Both are sewed in position. (*Mueller's operation.*)

Fig. 517.—Defect of Tibia Treated by Turning in Lower End of Fibula, and Securing Bony Union between the Upper Tibial Shaft and the Fibula.

Fig. 518.—Defect of Tibia Treated by Transferring Section of Fibula into Gap.

filling of bone cavities with foreign material have been devised. Detached bone chips should be classed among these materials, for in the light of modern knowledge their use cannot be spoken of as bone-grafting. When a piece of bone, whether fresh or old, is detached from its vital connections and implanted elsewhere into a bony defect, it becomes dead material and is amenable to the laws which govern the presence of foreign bodies under such circumstances. If the microörganisms of suppuration are present, it acts as

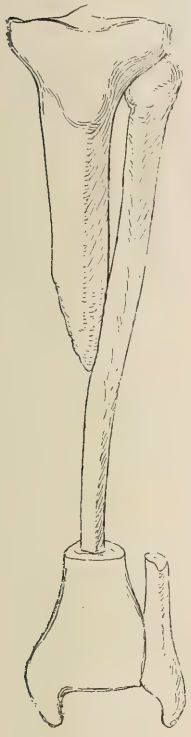


FIG. 519.

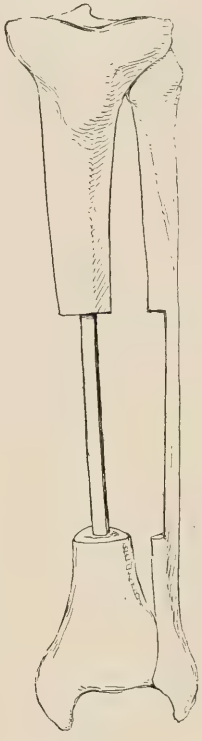


FIG. 520.

FIG. 521.

FIG. 519.—TIBIA CAUSED TO UNITE WITH SHAFT OF TRANSPOSED FIBULA.

FIG. 520.—DEFECT IN TIBIA TREATED BY TRANSPOSING PART OF THICKNESS OF FIBULA.

FIG. 521.—TRANSPLANTATION OF FIBULA INTO DEFECT OF TIBIA, BY SPLITTING LOWER END OF FIBULA AND PRESERVING OUTER MALLEOLUS.

This principle was developed by T. W. Huntington and J. S. Stone.

a foreign body, and suppuration will continue until it is removed. If it is covered in under aseptic conditions and has about it osteogenetic tissue, the process of new connective-tissue growth goes on until it becomes firmly incorporated in the new tissue. Its proteid cells break down and are absorbed, and the earthy framework which remains serves as a scaffolding into which the new tissue continues to grow. As the interstices become invaded by the new tissue, which histologically is the same as callus, the osteoclasts take up the solid material of the foreign bone, and thus, as an organized structure, it disappears. In the new tissue which replaces it osteogenesis progresses until it is transformed into new bone. This process is essentially the same if some substance other than bone is used. The materials which best lend themselves to this operation are bone chips, blood-clot.

sponge, and substances which are wholly or partially capable of being absorbed, thus furnishing a support to the newly growing bone-making tissue. The best substances for surgical use are those having interstices or those which are mechanical mixtures of ingredients of different degrees of absorbability. When a cavity is filled with these substances, if there is not enough skin or soft tissue to cover it, it may be covered with a layer of silver-foil or rubber tissue.

Organic tissues for purposes of filling bone cavities are employed with much success. Such tissues may be *living tissues* which do not lose their cellular character or identity after transplantation, but receive a blood supply from a new source and continue to live. Also organic substances are employed which are penetrated by new cells, absorbed, and disappear, but during the process serve as a scaffolding into which new bone develops.

Fat offers an excellent material for filling sterile bone cavities. A flap of fatty tissue may be cut from the patient's buttock or other fatty region, and fitted into the cavity. It is especially useful in the tibia. Pieces of fat as large as 20 cm. (8 inches) long have been successfully implanted in bone cavities.

Blood-clot was the first organic living substance used for this purpose. The first operation devised for aseptic cavity filling was that of Schede. He covered the sterilized bone cavity and permitted it to fill with blood. This coagulates, and the clot becomes penetrated by the new tissue and absorbed, just as implanted bone does. Although it is still much used and is a valuable expedient, it has the disadvantage that absorption goes on more rapidly than bone building. The success of the clot operation, like all of the expedients for cavity filling, depends upon the asepticity of the operation. The bone cavity must be sterilized and allowed to fill with blood. If it is lined with clean granulations, these may be incised or scraped to provoke bleeding. Often the operation is done immediately after removing dead bone, but with less promise of success than when performed as a secondary operation. Even the bacteria of the air threaten the success of this operation, and every precaution to exclude microörganisms must be employed, not only at the operation, but also at the first dressings.

Bone transference from another animal is carried out as follows: Under scrupulous asepsis the previously sterilized bone cavity is exposed. It is best that a tourniquet be not employed, in order to obviate the danger of having the transferred bone separated by blood after the wound is closed. The bleeding should be checked before the introduction of the transferred bone. The most convenient animal is a young dog. The required length, *e.g.*, of the dog's humerus, is removed by cutting forceps after the dog has been chloroformed to death. The muscle is stripped from the bone, it is immediately transferred to the waiting cavity, and the soft tissue is closed over it without drainage. It is not necessary that this piece of bone be thick, indeed, it is doubtful if as good results are secured with large as with smaller bones. An advantageous modification of this operation consists in splitting the fragment into several longitudinal pieces. This gives the connective tissue a better opportunity to penetrate. After the closure of the wound the limb should be put up in plaster-of-Paris or a splint to insure immobility of the parts.

Bone chips are prepared as follows: The tibia or femur of the cow is sawed into strips about 3 mm. (⅛ inch) in thickness. These strips are freed of periosteum and marrow and immersed in a 10 per cent. solution of hydrochloric acid in water. This solution is changed daily for ten days. The strips are then washed in sterile water, followed by alkaline solution,

and stored in a solution of ether saturated with iodoform. Before using, the ether should be washed out with alcohol. These strips may be cut into the desired length and the cavity filled.

Bone chips may also be made from the compact substance of the long bones of the cow, cut into cubical pieces about 1 cm. (⅓ inch) thick. These are decalcified in a 50 per cent. solution of hydrochloric acid for ten or fourteen days; they are then washed in weak alkaline solution, and preserved in absolute alcohol. When used, they are cut into small chips, sprinkled with sterilized iodoform powder, and packed into the cavity.

Other absorbable materials, such as catgut, cellulose fiber, sponge, and ivory; and *non-absorbable materials*, such as celluloid, perforated hard rubber, metals, and plaster-of-Paris, have been used. Brabant reports the successful employment of copper amalgam, which was pressed against the sides of a large cavity until the whole surface was covered.

Salt solution as a filling for bone-cavities has been used by Sherman with much success. The technic is similar to that employed when other substances are used. Hemostasis is secured and the tourniquet removed. The cavity is filled with normal salt solution and the tissues snugly closed over it without drainage.

Spermaceti wax for filling sterile bone cavities may be used with greater success. This is *the method of Mosetig-Moorhof*. The material used consists of 60 parts of iodoform, 40 parts of spermaceti, and 40 parts of oil of sesame. These ingredients are mixed and slowly heated to 100°C., (212°F.) and, when allowed to cool, form a soft solid which remains solid at the temperature of the body. When using it, it is heated to 50°C., (122°F.), being constantly stirred to keep the iodoform evenly distributed, and poured into the bone cavity, where it immediately solidifies. Its constituents are such that it is slowly absorbed after the manner of implanted bone, being permeated by new connective tissue which undergoes ossification. The rubber bandage should be used to render the limb anemic. Sinuses and diseased skin should be cut away, and the cavity should be left lined with healthy bone. The soft parts should be thoroughly freshened, and the cavity be both sterile and dry. The cavity should be cleaned out with the chisel and scoop, washed with salt solution, and sponged with a 2 per cent. formalin solution. This is followed by a hot-air blast for the purpose of drying. The filling is poured in from a bottle, the periosteum is closed with catgut, and the integument with fine silk. Elsberg overcomes the tendency of the filling to remain fluid and to become extruded from the cavity, by cooling it down to the consistency of putty, and then putting it into the cavity. This also helps to control oozing. It is best to remove the tourniquet constriction before introducing the filling, in order that all bleeding may be stopped. If oozing persist, it may be controlled by pressure, moist heat or the cautery.

This spermaceti filling is often of advantage after *resection of joints*. If a clean operation has been done, drainage may be dispensed with and the cavity left by the removal of the bone-ends filled artificially. This method has been most successfully used in the shoulder, hip, wrist, and ankle. In the knee and smaller joints, the filling is useful for smaller cavities resulting from the curetting out of diseased foci. The filling takes the place of drainage and permits long intervals between dressings.

The filling of defects due to—(1) localized caries, (2) tuberculosis, (3) injury, and (4) operative excisions, may be accomplished by any of the above described methods. Autoplastic operations with soft tissue have the disadvantage of leaving unsightly scars and distortions and tend the least toward strengthening the bone. The operations which aim to reproduce bone are the most useful.

In *isolated chronic abscess* of bone and in epiphyseal *caries* and *necrosis*, after laying open the cavity and scraping out the softened and diseased tissue, the cavity may be sterilized by 95 per cent. phenol, followed in a few minutes by alcohol, and this by saline solution, and bone filling introduced according to the rules laid down above. In epiphyseal disease there is often effusion into the joint, which may require aspiration or incision at the time of operation.

Tuberculosis of bone, if not complicated by mixed infection, is successfully treated by the immediate introduction of bone filling after the operative removal of the tuberculous bone. After removal of carpal and tarsal bones for tuberculosis, such filling in many cases obviates the necessity of amputation.

After accidental *compound fractures* with loss of bone, autoplastic operation with bone is indicated, but unless the possibility of infection has been overcome, bone filling should not be attempted. Later, if there is a defect, when aseptic conditions can be secured, any of the bone-reproducing operations may be done.

FIG. 522.—RESECTION OF LOWER END OF FEMUR FOR SARCOMA.

After operative excision of bone for *tumors* or other non-infective diseases the ideal conditions for bone plastic are present, and the surgeon may employ any of the above-described operations with the best hope of success.

(See Technic of Bone Grafting and Transplantation, below.)

RESECTION OF BONE FOR TUMORS

Conservative Operations for Tumors of Bone.—At present a small proportion of amputations and a large proportion of conservative operations are being done for tumors of bone. An operation as radical as resection of the affected part of the bone is not called for in all cases. In giant-celled sarcoma (myeloma) one should first curet if the disease has not gone too far. There seems to be little risk of metastasis by such an operation. When curettage fails to cure myeloma, resection of the disease is called for, to be followed, if necessary, by some operations for filling the defect.

In the case of a patient with osteosarcoma of the head and neck of the *humerus*, it has been possible successfully to resect the upper two-thirds of the bone with the adjacent fascia and muscular attachments, and replace the missing bone by the patient's fibula. The head of the fibula is articulated with the glenoid cavity, and the lower end is implanted deeply into the marrow cavity of the remaining lower third of the humerus. As a result of this operation my associate, C. Fulda, has been able to give the patient a movable shoulder-joint. The movements of the forearm were normal, and the strength of the leg was not materially affected (Fig. 523).

Resection of the lower half of the shaft of the tibia for sarcoma, leaving the lower epiphysis, is done. The gap is closed by splitting longitudinally the remaining half of the shaft up into the tuberosity, turning the segment down, and fixing it in place. Only 1.5 cm. (⅝ inch) shortening has resulted from such an operation, and a strong and useful leg secured (Figs. 524 and 525).

A portion of the *ulna* 14 cm. (5½ inches) long has been removed for sarcoma, and a piece of bone of the same length, 1 cm. (⅜ inch) wide and 2 mm. (⅛ inch) thick, chiseled from the crest of the tibia with its periosteum, fastened in the gap. The result has been a strong and useful arm.

Excision of only the diseased portion of the bone has long been practised in cases of benign tumors, but in the case of malignant growths the operation has been confined to the flat bones. Until the last decade, most surgeons

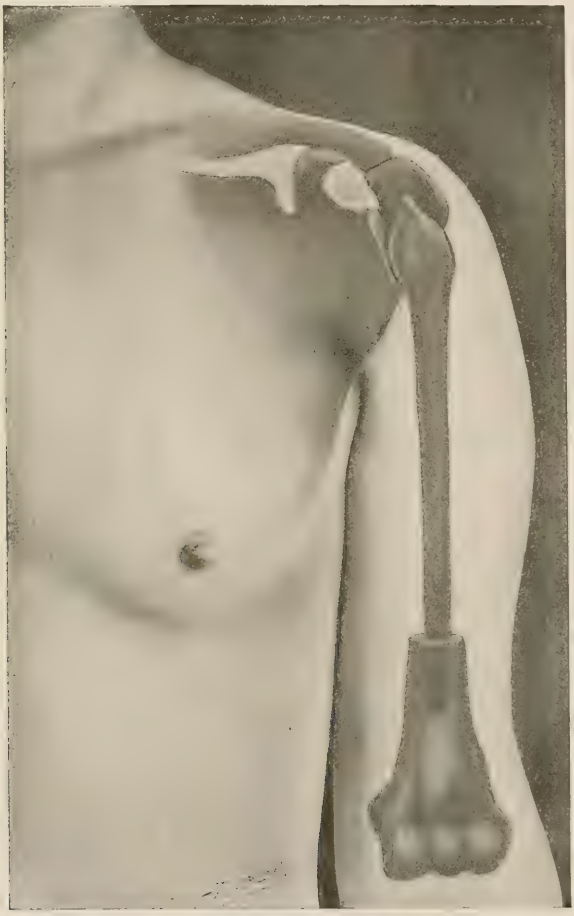


FIG. 523.—TRANSPLANTATION OF PATIENT'S OWN FIBULA TO REPLACE HUMERUS RESECTED FOR SARCOMA.

treated malignant diseases of the long bones of the extremities by amputation. Certain *giant-cell sarcomata* of the medulla of long bones, are so benign that they may be cured with the curet. Resection of the diseased bone in many cases gives results better than amputation, because less mutilation is done. Resection of the upper end of the tibia for sarcoma is often possible. In a case of giant-cell sarcoma of the lower end of the femur involving both condyles, the cavity was chiseled and scooped out, and the interior treated with chlorid of zinc. The cavity filled with new bone, and at the end of two and a half years there was no recurrence.

In many cases of malignant disease excision of the diseased portion of the bone is the best surgery. This is especially indicated when early diagnosis is made. The *x*-ray has contributed much to this end. Moreover, patients come more willingly to operation if they know that the limb is not to be sacrificed, and earlier operation is thus rendered possible. It is difficult to persuade patients with a scarcely discernible and painless swelling to consent to amputation. The operation almost invariably is deferred. But they will consent to excision, and for this reason its results are better. An

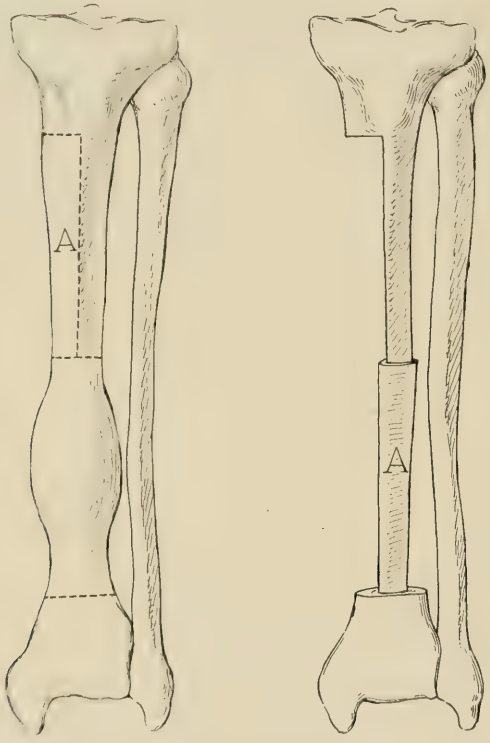


FIG. 524. FIG. 525.

FIG. 524.—TRANSPLANTATION OF HALF OF UPPER HALF OF SHAFT OF TIBIA TO FILL DEFECT AFTER RESECTION OF LOWER HALF FOR SARCOMA.

FIG. 525.—RESULT AFTER TRANSPLANTING HALF OF UPPER HALF OF TIBIA (*A*) INTO DEFECT OF SHAFT.

early excision is of more value than a late amputation, for it should remove all of the local disease as completely as amputation does. If metastases have taken place, amputation offers nothing better than excision. If metastases have not taken place, the sooner the tumor is removed the better; and it is necessary to remove only the tumor. In doing this, if much bone has to be sacrificed, the surgeon then is confronted not with a condition that threatens the patient's life, but only the usefulness of the limb. To restore this he has all of the resources of plastic surgery; and, if he fail, the worst that can come is the removal of a useless member.

The operation of excision of the long bones for malignant disease has been advanced to such a point that it is now a well-accepted procedure. Some surgeons advocate resection in all cases of sarcoma of bone where the disease

can be excised without injury to the vessels or without removal of so much tissue that the limb is rendered useless (Fig. 522).

Amputation is indicated when the resection necessary to remove all of the disease would leave a limb which is beyond restoration to usefulness. This is rarer than was but recently believed. Most cases of sarcoma of bone, in which resection would leave a limb which could not be made useful by osteoplasty, are not curable by amputation. It is a noteworthy fact that death following operations for sarcoma of bones has not been associated with local recurrence but with remote metastases.

The earlier operators laid stress on the kind of tumor that the surgeon had to deal with. This need be given but little consideration. In all cases the aim is to remove all the growth, irrespective of the degree of malignancy, and with as little damage to the parts as possible. Certain tumors, such as *giant-cell sarcoma*, occurring in the upper end of the tibia, the femur and the humerus can be removed by thoroughly curetting and chiseling out the bone cavity in which it is growing. This tumor is similar to epulis of the alveolar process which is best removed by a limited excision of the bone, performed with the rongeur or saw. Goldmann cured two cases of periosteal sarcoma of the tibia by resection. One was situated in the upper and middle thirds of the bone. Thirty centimeters (12 inches) of the shaft were excised, the fibula divided below its head, and the upper end of the peripheral fragment placed in a hole bored in the upper fragment of the tibia. Ten weeks after the operation the union was so solid that the leg would support the patient's weight. Two years after operation the fibula had become as large as the tibia of the other leg. In another case the tumor involved the lower two-thirds of the tibia, which was excised. The fibula was divided in two places, the freed segment fitted into the tibial gap, and sutured. Complete union was present in five weeks.

Accumulated evidence shows that in some sarcomata the disease can be cured by chiseling away the disease, and at the same time preserving the continuity of the bone; in other cases a resection of the entire thickness of the bone suffices; in others an amputation a short distance above the disease is necessary; and in extensive malignant growths involving the soft tissues as well as the bone, exarticulation at the joint above the disease is imperative. The results after resection and amputation are equally good if the tumor is confined to the bone, and almost equally bad if there is infiltration of the muscle.

In *giant-cell sarcoma* the most striking advantages have been found in conservative operation. *Bone cysts* of the dentigerous type do not even require resection, but in most forms all that is required is to remove the lining of the cyst to accomplish a cure. The secondary cysts, usually found in the medulla of long bones, are cured by opening, curettage and drainage. *Medullary fibroma* is benign and cured by the simplest resection. *Exostosis bursitis* should not be mistaken for malignant disease, as it requires the simplest resection.

Periosteal lipoma and *fibroma* are benign and require only removal of the tumor. *Enchrondroma* requires simple resection of the growth. *Adamantine epithelioma* has so little tendency to spread that its removal requires resection close to the tumor. *Myxoma* of bone should be treated the same as giant-cell sarcoma. *Myxochondrosarcoma* is cured by resection of the bone region in which it grows.

Periosteal osteosarcoma has a distinct capsule and is cured by resection of the part of the bone which it occupies.

The *small round-cell sarcoma, mixed-cell sarcoma, spindle-cell sarcoma,*

perithelioma, angiosarcoma and the other highly malignant varieties seem to give metastases so rapidly that amputation makes a poor showing. If local resection makes earlier operation possible it gives better results than amputation.

The operation of resection in preference to amputation is a great advance in operative surgery, and is not only destined to preserve limbs, but to lower the mortality of malignant disease. It is limitless in its field of application; it is applicable to all the bones of the extremities. It is not only possible to resect segments of long bones, but the whole bone may be removed and the patient left in a more useful state than he could be after amputation. This is illustrated by the removal of the humerus and the articulation of the ulna to the shoulder, leaving a woman who earned her livelihood by needlework a functionating hand. (See Technic of Bone Grafting and Transplantation, page 772.)

ARTHRECTOMY, ERASION OR SYNOVECTOMY

This operation consists in the removal of the synovial membrane lining the joint. The operation may include the removal of the diseased ligaments and other soft structures, and the scraping or tearing away of superficial disease of the cartilages or bones; but if section of the bone has to be done the operation constitutes an excision. The operation is indicated in disease which begins in the synovial membrane, and before advanced involvement of bone has taken place. It is indicated in most of the diseases which would demand excision if allowed to go on. It is preferable to excision in growing children. It is indicated in intractable chronic and suppurative synovitides, in tuberculous synovitis which resists milder measures, and in the fungous articuli of the old authors in which the capsule and the parasynovial tissue form a gelatinous mass 1 or 2 cm. (½ to ¾ inch) thick. Its advantages are that it does not interfere with the growth of the epiphysis; the ligaments about the joint are less damaged; shortening of the limb is not produced; and the dangers of the operation are less than in excision. If, however, the operation fail to remove all the disease, and recurrence takes place, excision is rendered more difficult. The operation will be described in connection with the knee-joint, to which it is chiefly applicable (page 752).

In the knee-joint the synovial membrane is dissected out through the U-incision. The sac behind the quadriceps may be exposed by a longitudinal incision at one side of the patella. When disease of the bone is discovered, it is best cut away clearly with a sharp knife. The surgeon need not remove sound bone as is done in resection. Foci of disease if deep should be followed up and gouged out. The object of the operation is to remove the disease. If cavities remain these may be filled with bone-filling preparation. Surgeons are now filling such cavities as large as a hen's egg, which a few years ago would have been treated by sawing off the whole end of the bone. By filling these cavities good results, without shortening, are secured.

OSTEOPLASTIC OPERATIONS

Osteoplastic operations for the defects of long bones following disease and injury have been described under operations for osteomyelitis, and the most important operations of that kind are to be found under that heading. There are, however, certain other methods of bone plastic which deserve attention.

In the skull, after trephining, the button of bone may be replaced and the permanent closure of the skull expected. The zygoma is turned down in

the flap of soft tissues in exposure of the temporo-zygomatic fossa, and sutured back in place. Osteoplastic resection of the skull is described under Surgery of the Head, Vol. II. This operation is a type of temporary resection, in which the bone is left attached to the overlying soft parts with the view of replacing it. The operation is practised on the spinal column to expose the cord, the flap containing the laminæ and spinous processes; it is practised upon the ribs, upon the lower jaw, in amputations to finish the bone ends, in rhinoplasty, and upon the bony prominences about the joints in operations for resection. The aim of the operation is that the vitality of the bone shall not be destroyed, and that the bone shall be replaced as living tissue.

Osteoplastic Operations for Cranial Defects.—In order to fill the defects resulting from loss of portions of the cranium any of the operations described under *Bone-grafting* and *Bone-filling* are indicated. There are also certain special operations for this purpose.

If the opening is small it may be exposed by a straight or curved incision through the scalp, the connective tissue removed from the dura, and from the opening, and the edges of the bone freshened. The trephine may then be applied to the healthy skull in the neighborhood, and the outer table cut through. The button thus marked out is lifted up and placed in the cranial defect with its periosteum against the dura, and the wound closed.

Larger defects may be filled by marking out a flap of the desired shape on the scalp, then sawing or chiseling through the outer table of the skull, lifting this up with the flap of scalp, and swinging it into place. In case of large defect of the parietal bone, a plate from the outer table of the opposite parietal bone may be removed from all of its connections, and fitted into the defect.

A flap of temporal fascia and periosteum to cover cranial defects is useful. The defect is exposed by a curved incision, and the scalp dissected from the temporal fascia. The scar tissue is removed from the defect and the opening slightly enlarged above to expose an edge of dura mater. A flap of temporal fascia, muscle, and periosteum is turned up from below. and the fascia is sutured to the edge of the dura, leaving the periosteum of the flap outermost. The scalp is then sutured over all. In this way not only a good substitute for dura may be secured, but also the development of bone from the reflected periosteum.

Skull defects may be closed by turning back a scalp flap and with the ronguer freshening the margin of the opening; then with a gouge and mallet a number of pieces from the outer table of the adjacent skull are chiseled off and distributed evenly over the defect; the flap of scalp is sewed in place over the bone chips. The chips eventually becoming incorporated into a solid bony plate. Areas as large as 6 to 7 cm. (2½ inches) by 3 to 5 cm. (1½ to 2 inches) have thus been treated and successfully covered with solid bone. (See Technic of Bone Grafting and Transplantation, page 772.)

OSTEOTOMY OF THE LONG BONES

Osteotomy consists in the cutting of bone, but the term is applied usually to the operative division of a long bone for the purpose of correcting deformity. Such deformity is usually due to badly united fractures, the distortion of rickets, or certain ankyloses following inflammation. The operation was originally performed through a free opening, but since the time of von Langenbeck it has been done through a minute skin opening just large enough to admit the chisel after the manner of tenotomy. The skin incision should be made in the direction of the long axis of the limb. The

bone is divided by means of the narrow chisel, called osteotome, and a mallet. The osteotome was perfected by Macewen, and differs from the chisel, which has only one side beveled, in that both sides are evenly ground. The cutting edge is from 1 to 2 cm. ($\frac{3}{8}$ to $\frac{3}{4}$ inch) in width. Osteotomes of different thickness may be used, the thinner being used last as the wound becomes deeper. These osteotomes are marked with the measuring grooves on the blade to determine the depth of the wound. The best mallets are those made of wood or rawhide (Fig. 502).

The extremity is best placed on a firm sand-bag to take up the impact of the mallet. The osteotome is introduced into the wound, passed down to the bone, and then rotated to the desired position. It should be held firmly in the closed hand with the inner side of the wrist resting on the skin

Fig. 526.—Method of Using Osteotome for Division of Bone.

so that it is under control (Fig. 526). It is driven a short distance into the bone and then rocked until it is loosened, and applied a little further along in the same line. It is well to keep the osteotome in contact with the bone, lest the location of the cut be lost. Gradually, in this way, it is worked along until the bone is divided. The osteotome should never become tightly wedged, but should always be kept loose by a rocking motion, both vertically and laterally, after each stroke of the mallet. The surgeon should have in his mind the important structures lying near the bone, and care should be exercised lest the chisel be driven into the tissues on the opposite side. The accepted practice is to carry the osteotomy nearly through the bone and then to complete the operation by forcibly fracturing. Often in children it is not necessary to make a complete fracture. The deformity is corrected, the small wound dressed without suture, and the bone treated as a fracture. The fine saw of Adams is sometimes used instead of an osteotome. In cases in which osteotomy is done for the purpose of producing a

false joint, passive motion must be continued every day from the time of operation, even though an anesthetic is required.

Cuneiform osteotomy (Fig. 527) consists in the cutting out of a wedge-shaped piece of bone to correct deformity too great for simple linear osteotomy. This is a complicated operation and requires an incision large enough to permit the removal of the wedge of bone. Cuneiform osteotomy is applied in extreme deformity of the tibia or femur resulting from rickets. It is rarely required in old ankylosis of the knee with flexion. In the latter case a wedge composed of the lower end of the femur and the upper end of the tibia is removed. The operation of cuneiform osteotomy is done ad-

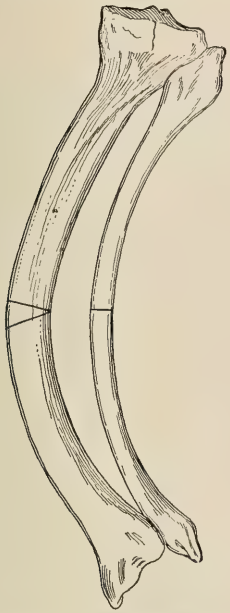


FIG. 527.—CUNEIFORM OSTEOTOMY.

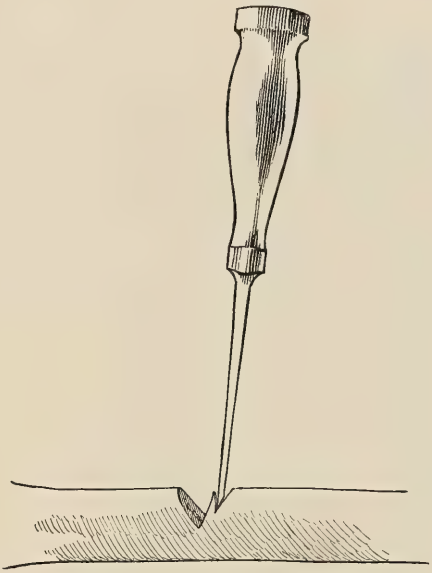


FIG. 528.—CUNEIFORM OSTEOTOMY. Method of removing a wedge of bone with the chisel.

vantageously by cutting out a notch in the bone with the bone chisel and then chiseling this larger and deeper until the desired cuneiform division of the bone is reached (Fig. 528).

Osteotomy of the Femur (For Ankylosis of the Hip-joint).—This operation is indicated in cases in which there is ankylosis with bad position of the thigh. The object is not to secure mobility, because this is rarely, if ever, accomplished, but to put the thigh in better position for walking.

Osteotomy of the upper end of the femur is done with the saw or with the osteotome.

Osteotomy of the neck of the femur (Adams) (Fig. 529, *A*) is done as follows: The left thumb compresses the soft tissues against the bone, the breadth of a finger above the great trochanter. At this point a long narrow-bladed knife is pushed in until it reaches the neck of the femur, and is then passed on in front of the neck, close to the bone. This incision is to make a passage for the saw, which should be introduced alongside of the knife before the latter is withdrawn. The neck is then sawn through from before backward, at right angles to its long axis. Care should be exercised to avoid cutting

the neck obliquely. This operation is not applicable to cases in which the neck has been destroyed or deformed; and inasmuch as in a large proportion of the cases of tuberculous ankylosis the neck of the bone has been destroyed, the field of the operation is limited. When the operation is done with the osteotome, it is through a small longitudinal incision just above the apex of the great trochanter. The osteotome is carried down to the neck of the bone, rotated to the position of a right angle to it, and the bone divided with a few strokes of the mallet.

Subtrochanteric osteotomy (Gant) (Fig. 529, *G*) is done through a longitudinal incision on the outer side of the thigh 2.5 to 4 cm. (1 to 1½ inches) below the great trochanter. The bone should be divided at a right angle just below the lesser trochanter, put up in extension in the corrected position,

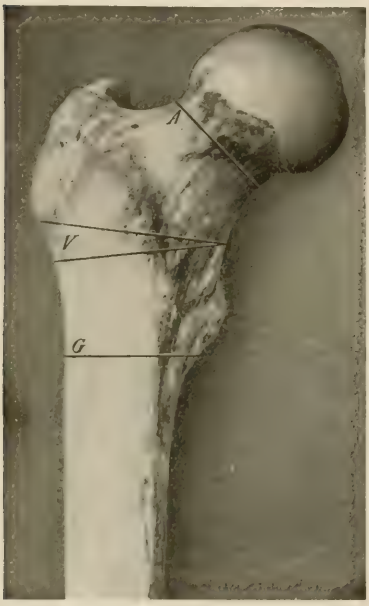


FIG. 529.—OSTEOTOMY OF THE UPPER END OF FEMUR.

A, Osteotomy of the neck (*Adams*); *G*, subtrochanteric osteotomy (*Gant*); V, intertrochanteric osteotomy (*Volkmann*).

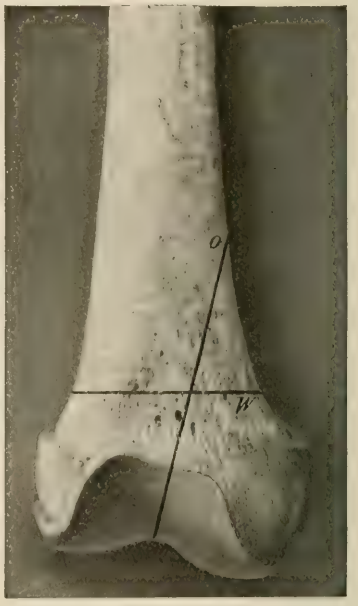


FIG. 530.—OSTEOTOMY OF LOWER END OF FEMUR.

W, Supracondyloid osteotomy (*Macewen*); *O*, oblique division of inner condyle (*Ogston*).

and treated as a fracture of the thigh. The operation devised by Volkmann divides the bone between the greater and lesser trochanters (Fig. 529, *V*). Volkmann devised another operation by which he rounds off the upper end of the lower fragment, scoops out a cup-shaped depression in the great trochanter, and by passive motion secures a joint at this place.

The operations of Adams and Gant are usually employed for the correction of deformity following ankylosis of the hip in a faulty position, the latter having the wider range of usefulness. In all of these operations tenotomy and division of contracted soft parts are often required to secure the best results.

Osteotomy of the Lower End of the Femur.—This operation is required usually for knock-knee and for deforming ankylosis of the knee-joint.

Osteotomy for knock-knee (genu valgum) is performed in all adult cases

requiring treatment and in aggravated cases in children. If the case remains aggravated by the fourth year operation is advisable. In the normal femur the epiphyseal line is on a level with the tubercle of the adductor magnus muscle and crosses the bone horizontally. In knock-knee this line is oblique, but still parallel with the articular surface, because genu valgum is due to a lateral overgrowth of the diaphysis and not of the epiphysis.

Supracondyloid Osteotomy of the Femur from the Inner Side (Macewen) (Fig. 530, *W*).—This is the most generally employed of the osteotomies for knock-knee. The patient lies upon his back with the knee and thigh flexed and the thigh supported on a sand-bag on its outer side. If operating on the right leg the surgeon stands to the outside; if on the left leg he stands opposite the left hip. A short incision is made on the inner side of the thigh 1.25 cm. (½ inch) anterior to the tendon of the adductor magnus and 1.25 to 2 cm. (½ to ¾ inch) above the adductor tubercle. This should bring the middle of the incision on a transverse line drawn about a finger's breadth above the external condyle. The knife is passed to the bone, and before it is withdrawn the osteotome is inserted. The osteotome is then rotated and the bone divided transversely above the epiphyseal line. In doing this it is well to begin with osteotomy on the postero-internal aspect of the bone, driving the osteotome forward and outward. The cut is then advanced to the inner side and then toward the front of the bone. The osteotome is rocked up and down in order to widen the cut. The posterior and outer parts of the circumference remain undivided, and are fractured after the osteotome has advanced through three-fourths of the bone. This operation may be done through a transverse incision, which makes the manipulation of the osteotome easier. After the bone is divided the wound is covered with a small dressing and the limb put up in the corrected position in plaster-of-Paris. The splint should be applied for about four weeks, and the child may be allowed to stand on the leg in about six weeks. By securing a partial or green-stick fracture of the bone in its outer fourth; the displacement of the lower fragment, incidental to complete fracture, is obviated.

Supracondyloid Osteotomy of the Femur from the Outer Side (Fig. 530, *W*).—The patient lies upon the back with the thigh and the knee flexed upon a sand-bag. The thigh is adducted and an assistant steadies the leg. A longitudinal incision not longer than 2.5 cm. (1 inch) is made 2.5 or 5 cm. (1 or 2 inches) above the external condyle. This incision is made on the outer side of the thigh. It is carried through the iliotibial band down to the bone in front of the tendon of the biceps. The osteotome is inserted, rotated to the transverse position, the bone divided through about three-fourths of its thicknesses and the division completed by fracturing it. The limb is then put up straight in the corrected position.

Oblique Division of the Internal Condyle (Ogston) (Fig. 530, *O*).—The point of a narrow-bladed knife is passed into the bone on the inner surface of the thigh about 5 cm. (2 inches) above the adductor tubercle. The point of the knife, with the cutting edge against the bone, is passed forward, downward, and outward till the groove between the front of the condyles is reached. The joint is opened by this incision. A fine saw is passed down in front of the bone at the junction of the inner condyle and the shaft, and the bone is sawn through obliquely. This operation may be done even more easily with the chisel. The inner condyle is completely detached, and by adducting the leg it is displaced upward and the genu valgum corrected. This operation has the decided disadvantage of opening the joint and of involving the epiphysis.

Other operations of less frequent utility are the following (Fig. 531):

Osteotomy of the Tibia.—*Osteotomy of the Tibia below the Tuberosities* (Fig. 531, *h, i, k*).—This operation is required to remedy the deformities following rickets, causing knock-knee, bow-legs or other distortions; to correct the deformity of vicious union of fractures; and for deforming ankylosis of the knee. The bone is exposed on its internal surface just below the tuberosity by a longitudinal or transverse incision, and divided from within outward by the osteotome. To prevent injury of the popliteal structures a thin, flat retractor may be passed across the posterior surface, close to the bone. There is less danger of injury to the peroneal nerve if the fibula is also divided, and still less danger if a cuneiform osteotomy of the tibia is done.

Osteotomy of the Shaft of the Tibia.—This operation is indicated for extreme curvatures and in cases in which osteoclasis is not indicated. A short

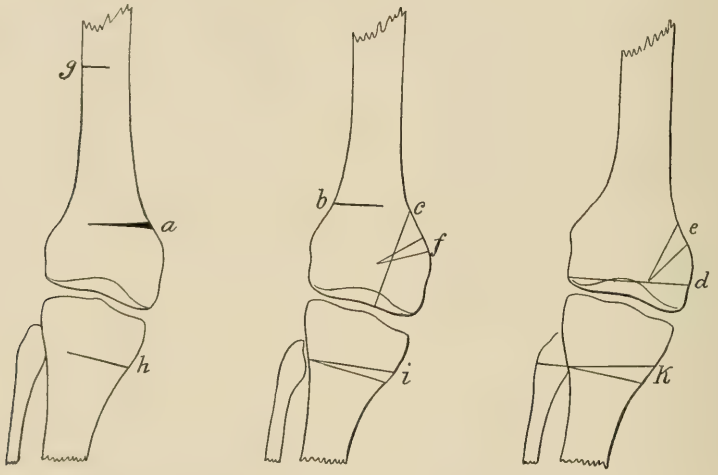


FIG. 531.—LINES OF OSTEOTOMY ABOUT THE KNEE-JOINT.

Osteotomy of both condyles for knock-knee (*Annandale, d*); wedge-shaped osteotomy of the inner condyle (*Macewen, e*); wedge-shaped osteotomy of the inner condyle (*Chiene, f*); linear osteotomy of the shaft of the femur (*Reeves, g*); linear osteotomy of the tibia (*Billroth, h*); wedge-shaped osteotomy of the tibia (*Mayer, i*); osteotomy of the tibia and fibula (*Schede, k*).

incision is made over the internal surface of the bone at the level of the deformity, the soft tissues dissected up for a short space, the bone partially divided with the osteotome and fractured. In extreme deformity a wedge-shaped osteotomy, or osteotomy in two places, may be required. An actual lengthening of the bone is produced if the division of bone is made on the concave aspect of the deformity, for in producing the fracture and straightening the bone the gap made by the osteotome is widened. Tenotomy of the Achilles tendon is sometimes required.

Osteotomy Combined with Resection of Long Bones.—A section of bone is sometimes required to be removed on account of *unequal length of parallel bones* when lengthening of the bone is not to be considered. This is the case when one femur is so much longer than the other that curvature of the spine is developing or an artificial lift under the foot is necessary; or in cases in which a leg bone or forearm bone outgrows its fellow and distorts the ankle or wrist. If, for example, it is desired to remove 5 cm. (2 inches) of the shaft of the femur, longitudinal incision is made at the middle of the outer aspect

of the thigh from 10 to 15 cm. (4 to 6 inches) long, and carried down to the bone. The periosteum is elevated over 8 or 10 cm. (3 or 4 inches) of the bone, and the overlying soft parts separated with it. Five centimeters (2 inches) are then measured off, and above and below these points the bone is drilled through for the passage of the wire to hold the divided ends. The wire saw is then passed, and the bone sawed obliquely in such a way that a wedge-shaped end is secured on one fragment and a wedge-shaped indentation to receive it is secured on the other (Fig. 532). The fragments are then wired. Instead of wire or suture for this purpose, metal plates may be screwed to the bone to hold the ends together, or a medullary plug made of the excised segment.

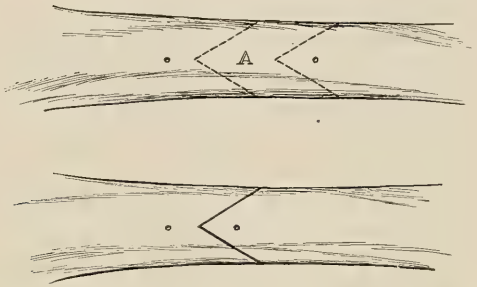


FIG. 532.—REMOVAL OF SECTION TO SHORTEN BONE.
Note that holes have been bored for wire or suture before the section (*A*) is removed.

Instead of osteotomy, plaster-of-Paris dressings in young children cause a softening of the bones which permits bending without cutting. This is true of healthy as well as rachitic children. If a new plaster case is applied every two or three weeks and forcible correction made as far as possible, the softening of the bone which goes on will permit the shaping of bones to a remarkable degree.

EXCISIONS AND RESECTIONS OF BONES

Excision and Resection of the Upper Jaw.—These operations are usually understood to involve but one of the superior maxillæ, although the simultaneous removal of both bones is sometimes required. Excision of the upper jaw is done on account of malignant tumors of the bone or antrum of Highmore, osteitis and necrosis. Temporary osteoplastic resection is done to give access to the nasopharynx for the removal of tumors of that region. The bony connections which have to be divided by instruments are: (1) the nasal process, (2) the malar process, and (3) the hard palate and alveolar process. The connections with the other bones of the skull are not so strong that they need be cut. The operation is essentially a bloody one. Many surgeons employ primary tracheotomy and the tampon canula, or tamponing the pharynx to prevent blood entering the trachea, the head being slightly flexed upon the chest or extremely extended. A much better procedure is the temporary or permanent ligation or temporary clamping of the external carotid artery. When this is done the chief difficulty of the operation is removed and excision of the upper jaw becomes a simple procedure. The contrast between the old bloody operation and the ease of the procedure after ligation of the external carotid is very striking. If occlusion of the carotid is not practised, the hemorrhage is best controlled by packing with iodoform gauze, and making firm pressure immediately after the removal of the bone (see Surgery of the Mouth, Teeth and Gums, Vol. II).

Many of the operations upon the face call for incisions at acute angles. Such incisions leave sharp points of skin to be sutured. I have found it more satisfactory, for cosmetic reasons, to avoid making these sharp points and to make curved incisions instead. The curve lends itself better to suturing, and the sharp angle, which is apt to necrose, is obviated.

Excision of the Upper Jaw by the Mediolateral Incision (Nélaton, Weber, Fergusson) (Fig. 533, *A*, *B*, *C*).—The patient lies with his head turned toward the sound side. The anesthetic mask is removed and the administration of the anesthetic continued through a tube inhaler, or the mask is reapplied

FIG. 533.—LINES OF INCISION FOR OPERATIONS ON UPPER AND LOWER JAWS.

ABC, Mediolateral incision (*Nélaton*); *E*, external incision (*Ollier*); *D*, external incision (*Velpeau*); *IC*, median incision (*Dieffenbach*); *PRS*, Boeckel's operation; *VW*, incision for temporary division of the lower jaw; *WXZ*, incision for resection of lower jaw.

during the operation when necessary. In this operation intratracheal insufflation, rectal anesthesia, or some other of the methods which do not require a face mask, are best. An incision is begun 1.25 cm. (½ inch) below the inner canthus of the eye, and is carried down along the side of the nose to the ala, around the ala in the groove where it is joined to the face, thence horizontally to the septum nasi, and then directly downward to the free border of the lip. This incision is supplemented by one passing from its upper end outward beneath the eye, directly on the lower border of the orbit, and terminating 1.25 cm. (½ inch) below the external canthus. These incisions should lay open all of the soft tissue down to the bone. The flap representing the soft tissue of the cheek is dissected from the upper jaw, so

that the malar process is exposed. The nasal cartilage is separated from the edge of the bone. The periosteum at the lower margin of the orbit is incised and with a thin sharp elevator lifted up from the orbital surface of the bone. The wire-saw or chain-saw is then passed through the sphenomaxillary fissure, and the malar process divided (Fig. 534, *B*). The nasal process is then divided with the bone-cutting forceps. The mucous membrane and periosteum of the hard palate are divided transversely opposite the last molar tooth, and in the median line from this incision forward. The soft palate is then separated from the hard palate through the transverse

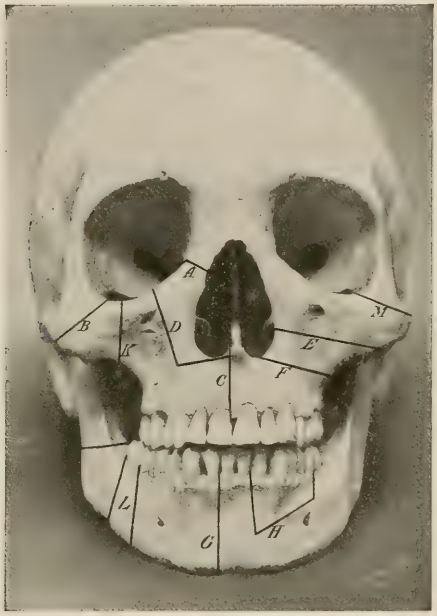


FIG. 534.—LINES OF DIVISION OF BONE IN RESECTIONS OF THE UPPER AND LOWER JAWS.

ABC, Excision of the upper jaw; *B*, *K*, different points of external division; *EC*, resection of the lower segment of the upper jaw (*Guérin*). (The line *C* should fall on the side of the nasal septum toward the bone to be removed.) *FM*, Resection of the upper segment of the upper jaw; *D*, resection to gain access to the nasopharynx (*Boeckel*); *H*, resection of the alveolar process; *G*, excision of half of lower jaw; *L*, osteotomy of lower jaw.

incision by means of the elevator. The middle incisor tooth is drawn and the hard palate divided by the saw, chisel, or forceps, close to the septum. The mucous membrane lining the cheek is then cut from the alveolar process with curved scissors. Lion-jaw forceps then grasp the bone, and by a rocking motion it is loosened from its remaining attachments, which are the palate bone behind and the ethmoid bone above (Fig. 535). The superior maxillary nerve, emerging in the fissure, should be divided as far back as possible. The divided reflection of mucous membrane is sutured behind to the palate and in front to that of the opposite side. The skin wound and the divided lip are carefully approximated, and the cavity from which the bone was removed is packed with iodoform or balsam gauze.

If the disease does not involve the mucous membrane of the hard palate, the operation should be modified as follows: An incision should be carried through the mucous membrane and periosteum of the hard palate close to

FIG. 535.—EXCISION OF THE UPPER JAW THROUGH THE MEDIOLATERAL INCISION. Mouth-gag in place, soft parts retracted, bone-forceps wrenching out bone.

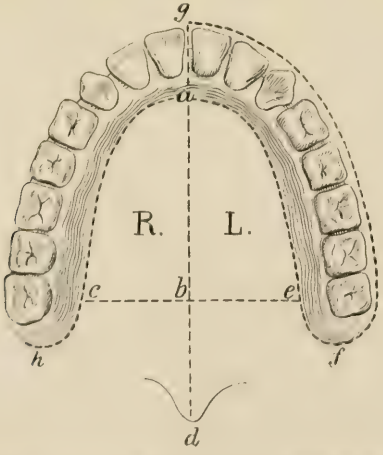


FIG. 536.—MUCOUS MEMBRANE AND PERIOSTEAL INCISIONS FOR RESECTION OF UPPER JAW.

R, Right; *L*, left. The incision *abch* is made for excision of the right upper jaw. The bone is divided along the right side of the line *gb*. If there is no disease of the hard palate, the incisions *ach* and *cb* may be made. Ollier's subperiosteal excision is *afg*.

the alveolar process of the diseased bone instead of in the median line. The valve of soft tissue should be elevated, and when the bone is removed this may be sutured to the edge of mucous membrane of the cheek and the nasobuccal septum retained complete (Fig. 536).

Another point which I have found most useful in cases in which the disease has not extended toward the malleolar process is to saw the outer part of the bone forward in such a way that all or a large portion of this process is left attached to the malar bone. At this location, in sawing from the sphenomaxillary fossa forward, the surgeon has the choice of bringing the anterior end of the bone division inward or outward over a variation of more than 2.5 cm. (1 inch). This may depend upon the position of the disease.

FIG. 537.—LINES OF INCISION FOR OPERATIONS ON UPPER AND LOWER JAWS.

FGH, U-incision for resection of upper jaw (*Langenbeck*); *TO*, incision to gain access to the nasopharynx (*Ollier*); *NFO*, Langenbeck's osteoplastic resection; *VWX*, incision for resection of half of body of lower jaw; *VWXZ*, incision for resection of half of lower jaw.

The more of this process that can be left, the more support and prominence there are for the cheek, and consequently the less the deformity (Fig. 534, *B*, *K*).

Excision of the Upper Jaw by the External Incision (Fig. 533, *D* or *E*).—An incision through the whole thickness of the cheek is carried upward and outward from the angle of the mouth toward the outer canthus of the eye. The incision may be curved with its convexity outward (Velpeau) or straight (Ollier, Liston). This incision should end over the middle of the malar bone. The soft tissues are then dissected up and retracted from the bone to be removed, the bone is divided, and the operation proceeded with as described above. This incision has the disadvantage that it divides the branches of the facial nerve and the curved incision is apt to divide Steno's duct.

The *cheek-flap operation of Langenbeck* (Fig. 537, *FGH*) carries an incision from the side of the nose, beginning at the lower end of the suture between the nasal bone and the upper jaw, curves downward to the juncture of the upper lip and the cheek, and thence upward to end over the middle of the malar bone, thus making a U.

The *median operation of Dieffenbach* (Fig. 533, *IC*) is characterized by an incision, beginning at the root of the nose and passing down the median line of the nose and through the lip. To this is added a transverse incision from the upper end of the first to the inner canthus of the eye.

The *method of Malgaigne* adds a median division of the upper lip to the *external incision* of Velpeau.

Simultaneous Excision of Both Upper Jaws.—This operation is best done by means of the *external incisions* passing from the angles of the mouth to the middle of the malar bones. The soft tissues lying between these two incisions, together with the cartilages of the nose, are dissected up from the two maxillæ as far as the orbits, and the flap turned up over the forehead. The operation is proceeded with as described above under the *mediolateral incision*, except that the two bones are not separated, but are removed together. The malar processes are divided in the usual manner. The nasal processes may be divided separately by bone forceps or together by passing the wire-saw from one orbit into the other through the lacrimal bones. As much of the periosteum of the hard palate as possible should be saved by employing a curved incision near the alveolar margin and stripping it back, leaving it connected posteriorly. The soft palate is separated from the bone. The bones are then twisted downward and forward from their other attachments. This is a less difficult operation than removal of the single bone, provided, of course, that occlusion of both external carotids has been practised.

Subperiosteal Excision of the Upper Jaw.—This is done through the *external incision*, although the *mediolateral incision* is well adapted to the operation. If necessary, median division of the upper lip may be combined with the external incision of Ollier. In this operation the periosteum is left attached to the overlying soft tissue and is elevated with it. The operation is indicated in cases in which the periosteum is not diseased and in operation for exposure of the nasopharynx. After making the skin incision the mucous membrane is divided by an incision beginning at the median line in front, on the outer surface of the alveolar process, and carried backward, close to the edge of the gum, around the last molar tooth, and then forward in the same manner on the inside of the alveolar process to a point opposite its beginning (Fig. 536, *g*, *f*, *a*). An incision through the periosteum is then carried upward from the beginning of the first to a point just external to the anterior nasal spine. The periosteum is then stripped back from the anterior surface of the bone. When the infra-orbital canal is reached, the nerve is divided at its point of emergence. The stripping-up of the periosteum is continued into the orbit and to the limit of the bone. The lacrimal sac and duct may be left uninjured, adherent to the periosteum. The separation of the periosteum in the roof of the mouth is continued as far as the median line. The malar process and the nasal processes are divided, the incisor tooth removed, and the chisel used to divide the bone obliquely back to the median line, and thence backward through the rest of the hard palate. The bone is then removed with strong forceps, and, finally, the mucoperiosteal flap from the hard palate is sutured to the periosteal flap above.

Resection of the Lower Segment of the Upper Jaw.—The removal of the one below the infra-orbital canal by the *operation of Guérin* is as follows

(Fig. 533, *KM*; Fig. 534, *EC*): A curved incision, with its convexity outward, is carried from the upper part of the wing of the nose to the angle of the mouth, following the curve usually present in this situation. The soft parts and the nose are dissected from the bone and retracted. A saw is passed into the naris, and the bone is sawn horizontally outward, the saw cut ending in the malar process. The soft structures of the palate are divided transversely, as described above, and the hard palate near the middle line, and the bone twisted out. This procedure lends itself to the subperiosteal operation. It gives a good view of the nasopharynx and is indicated for disease of the bone not involving the orbital plate.

Resection of the Upper Segment of the Upper Jaw (Fig. 534, *FM*).—For this operation the best incision is the *mediolateral*. The soft parts are raised from the bone and the periosteum is detached from the orbital plate. The malar and nasal processes are divided as already described, and a horizontal cut made with the saw from the naris outward, passing above the alveolar process. The bone thus freed is wrenched out.

Osteoplastic Resection of the Hard Palate (Fig. 536).—This operation is done to give access to the nose or nasopharynx. The posterior portion is resected by carrying a median incision through the soft palate and mucous membrane and periosteum of the hard palate, as far forward as is desired. A transverse incision is carried from the front of this to one or both sides, and the mucoperiosteal flap separated from the bone. The mucous membrane on the floor of the nostril is divided close to the septum and pressed back. As much of the hard palate as is necessary is then removed. This may involve one or both sides; if the latter, the vomer is divided with forceps. The operation is completed by suturing the soft parts back in place.

Osteoplastic resection of the anterior portion of the palate is accomplished by extracting the canine teeth, dissecting the upper lip away from the bone until the nasal cavity is exposed, and then dividing the alveolar process and the hard palate by two lines of parallel incisions running from the canine sockets back to the soft palate. The vomer is divided, and this bone-flap, attached posteriorly, is turned down. It may be replaced and sutured in position at the close of the operation.

Resection of the alveolar process (Fig. 534, *H*) is practised for the removal of limited disease, such as epulis. The section to be removed should be marked out and denuded of healthy mucous membrane and periosteum. Teeth which are in the way should be removed, and the anterior and posterior limits of the resection defined by the saw. The upper ends of the saw cuts are connected by a line marked with the chisel, or the horizontal division may be made with a saw. The rongeur is useful in extending the operation in the direction of any suspected disease.

Operations through the Upper Jaw to Gain Access to the Nasopharynx.—Subperiosteal operation through the upper jaw, described above, is the most satisfactory for securing free access to the nasopharynx. Temporary resection of the upper jaw is done by means of an osteoplastic flap having its base at the nose and its apex over the malar bone, and leaving the alveolar process and hard palate (Langenbeck, Fig. 537, *NFO*).

The *operation of Boeckel* is a valuable procedure (Fig. 533, *PRS*; Fig. 534, *D*). An incision is carried from the root of the nose, curving downward along the side of the nose to the wing of the nostril, and thence outward upon the cheek. A second incision begins at the origin of the first and curves downward and outward along the lower margin of the orbit to the infra-orbital foramen, avoiding the lacrymal sac. This flap is raised with the periosteum. A pyramidal section of the upper jaw is then removed with the

chisel, having the outer border of its base marked by a vertical line just internal to the infra-orbital foramen, and the base representing the rest of the anterior surface of the bone above the alveolar process. This mass bears the middle and inferior turbinated bones

The *operation of Ollier* (Fig. 537, *TO*) begins with an incision external to the ala which passes upward to the middle line at the root of the nose, at the level of the inner canthi of the eyes; a similar incision is made on the other side, making an inverted V. The apex of the angle should be rounded so as not to make a sharp point. The bone is sawn through in the line of incision and the nose turned down as an osteoplastic flap. The septum is removed or pressed aside, the nasopharyngeal condition dealt with, and the operation continued by replacing the nose and suturing it in place. This operation may be modified for the removal of a large tumor by making the angle greater between the two arms of the V and carrying the lower extremities of the incision farther away from the alæ.

The *operation of Annandale* divides the mucous membrane at the lip-alveolar junction, dissects up the nose from its bony attachments, divides the alveolar process and hard palate near the median line, and pries apart the divided bones to increase the space of access.

The *operation of Denker* for reaching malignant tumors laterally does not divide the skin. The soft tissues of the mouth are widely retracted and an incision through mucosa and periosteum is carried along the alveolar process from the last tooth horizontally forward, nearly to the middle line, and thence up to the apertura pyriformis. The periosteum is elevated as far up as the lower border of the orbit and the nasal opening, and retracted upward. The bone is then removed from the nasal margin, opening the antrum and continuing as far outward as necessary.

Osteoplastic-flap operations preserve the bone. In the operations devised by Langenbeck and Boeckel it is best, if possible, to make an osteoplastic flap, leaving the soft tissues of the cheek connected to the bone, and replacing all of the parts at the conclusion of the operation.

Excision and Resection of the Lower Jaw.—The whole or any part of the lower jaw may be removed. Operation is usually performed for tumor or necrosis, and involves only a part of the bone. The surgeon should spare as much of the bone as possible, and should not endeavor to perform a typical operation, but should suit each operation to the requirements of the case. The extent of the incision should vary with the amount of bone to be removed. The important structures lying close to the bone to be borne in mind are the facial and internal maxillary arteries, the facial and lingual nerves, and the submaxillary and parotid glands and their ducts. Healthy periosteum and mucous membrane should be preserved as far as possible. Operations, removing the body of the bone, require detaching from their anterior supports the muscles holding the tongue and thus permitting it to drop back upon the glottis; a suture, therefore, should be passed through the tongue to hold it forward during the operation. After the operation as perfect a suture as possible should be made, uniting the buccal mucous membrane.

Resection of Half of the Body of the Lower Jaw (Fig. 533, *VWX*).—A median incision is made from the junction of the lower lip and the chin downward to a point just below the symphysis under the chin. It is not necessary to divide the lip, although it is commonly done. Another incision is carried along beneath the jaw as far as the angle. The facial artery and vein are ligated and the bone uncovered. If free of disease, the mucous membrane and periosteum are divided close to the teeth, inside and outside,

and stripped down with an elevator. A tooth is drawn and the jaw divided anteriorly with a wire-saw. The side to be removed is retracted forward, and the separation of the periosteum and muscles completed. Division as far posteriorly as necessary is then made, the bone is removed, and the mucous membrane covering the defect is tightly sutured with the view of preventing saliva entering the wound. The wound should be closed with drainage as its posterior part.

This operation may be done with simply a vertical incision in the middle line, or with the horizontal incision under the jaw alone, or through the mouth without any skin incision. In dividing the bone it is well, if possible, to make the division a little to one side of the median line, in order to preserve the insertion of the geniohyoglossus muscle. The incision to be employed will depend much upon the extent and location of the disease to be removed.

Resection of Half of the Body and the Ramus of the Lower Jaw (Fig. 533, *VWXZ*).—The median incision is made and continued, as above, horizontally along the lower border of the jaw to the angle, and thence upward to the level of the lobe of the ear, ending short of the main fibers of the facial nerve. The bone is then uncovered through this wound, externally and internally, as far as the mucous membrane. The jaw is then divided anteriorly and retracted outward. The division of the mucous membrane and the muscles is next accomplished, and the inferior dental nerve divided. The ramus is denuded of its soft tissues with the elevator, and, as the jaw is forcibly depressed, the attachment of the temporal muscle to the coronoid process is divided by means of curved scissors. A small round retractor passed close to the bone and drawn strongly upward protects the facial nerve from being wounded. The head of the bone is then easily twisted out of the glenoid fossa as the ligaments are divided. The internal maxillary artery, lying close to the neck of the condyloid process, should not be injured. The closure of the soft parts is described above.

Excision of the Whole of the Lower Jaw.—This operation is done through an incision extending around the border of the jaw from a point opposite the lobe of one ear to the other. The jaw should be divided in the middle and each half removed separately.

Resection of the alveolar process (Fig. 534, *H*) is accomplished without a skin incision just as described for the upper jaw. An effort should always be made to preserve the continuity of the jaw.

Temporary Division of the Lower Jaw (Fig. 533, *VW*).—This operation is undertaken when it is desirable to render more accessible the floor of the mouth, the palatine arch, the tongue, the nasopharynx and the base of the skull. The division may be made laterally or in the middle and the bone segments retracted.

The Median Operation.—An incision is made in the median line and under the chin; the point of a narrow knife is then passed behind the symphysis and brought out through the frenum of the tongue close to the bone. A middle incisor tooth is extracted and the bone divided with a wire-saw. Retractors may then be used to separate the bone and give access to the floor of the mouth, the sublingual gland and the tongue. The bone is united with silver wire.

The Lateral Operation.—An incision passes downward from the angle of the jaw to the level of the larynx. The details of the rest of the procedure are the same as for the median operation. Through this wound the bone is exposed and divided just in front of the ramus. By retracting the two parts of the bone a wide opening is secured. This gives access to the posterior

portion of the tongue, the palatoglossal arch, the pillars of the fauces, and all of the pharynx.

Resection of a segment of the lower jaw may be practised to give a larger opening than is secured by either of the above operations.

Operations for Ankylosis of the Lower Jaw.—Ankylosis, due to the formation of scar tissue along the ramus of the jaw as a result of inflammatory disease, is treated by osteotomy and the formation of a false joint.

Esmarch's operation (Fig. 534, *L*) consists in the removal of a wedge-shaped piece of bone from the portion of the body lying just in front of the masseter muscle. This is done through an incision along the lower border of the jaw. If the adherent tissue does not extend the full length of the ramus, it is better to make a horizontal section of the ramus and prevent bony union by constant motion. This operation can be done by a chisel passed through the mouth to the ramus, or the bone may be exposed by an external incision. As most ankylosis is due to disease of the joint or its ligaments, this operation is rarely indicated. It is only to be considered in cases in which there is fixation along the ramus.

Excision of the condyle is performed when the ankylosis is due to conditions within the joint. The old operation was done as follows: A vertical incision is made just in front of the temporal artery, beginning just above the zygoma and ending above the facial nerve, which emerges on a level with the lobe of the ear. This incision, if necessary, may be supplemented by a second one at right angles to its upper end and passing along the lower margin of the zygomatic arch. The joint is opened, the neck of the condyle divided, and the head of the bone removed. The parotid gland, the internal maxillary artery, and the facial nerve should be avoided. Passive motion is necessary to supplement the operation, even though it must be practised under an anesthetic. Operation on both sides is performed the same as above.

It is easier to tell about removal of the head than it is to execute the operation. There is so much danger of tearing out the thin floor of the glenoid fossa and of rupturing the internal maxillary artery, that the operation should be attempted only when the head is very loose. The modern operation consists in dividing the neck, and interposing a flap of soft tissue to create a new joint (see Arthroplasty, page 757).

Prosthetic Apparatus to Remedy Defects after Resection of the Jaws.—Many contrivances have been devised to correct deformities following removal of the whole or parts of the jaw-bone. The most successful are made of hard rubber, having approximately the size and shape of the bone removed, and carrying teeth corresponding to those missing. Two important problems confront the surgeon—the rapid contraction of the parts after removal of the bone, and the difficulties of retaining in place such prosthetic appliances. The first of these is met by the introduction of prosthetic apparatus as early as possible after operation, before cicatricial contraction has advanced. The perfection of this branch of surgery is in the hands of the prosthetic dentists, who have devised means for the retention of such apparatus.

Deformities which for some reason are not remedied in this manner may be improved, at least so far as the appearances of the face go, by plastic operation or by the injection of paraffin to fill out the sunken features.

Prosthesis of the Upper Jaw.—After resection of the alveolar process a rubber denture, built up to fit the jaw, serves most satisfactorily. For removal of the upper jaw the dentist should make an impression of the mouth before operation. With this as a guide he should construct an upper plate which should be inserted within a week after the operation. This

primary plate need not have teeth upon it, but is intended to keep the parts patent while the wound is cicatrizing and the surfaces are becoming covered with epithelium. A permanent plate should be made, embodying any modifications for comfort which the first plate has suggested, and also supplying the missing teeth and, most important, having on its upper surface a "plumper." This "plumper" is a projection or protrusion, built upon the plate, to supply the defect of the missing bone. It may be made as a hollowed depression on the plate. It is not necessary that it should be large; indeed, if it is not put in immediately after the operation there will

FIG. 538.—PLATE WITH "PLUMPER," WORN AFTER RESECTION OF UPPER JAW.

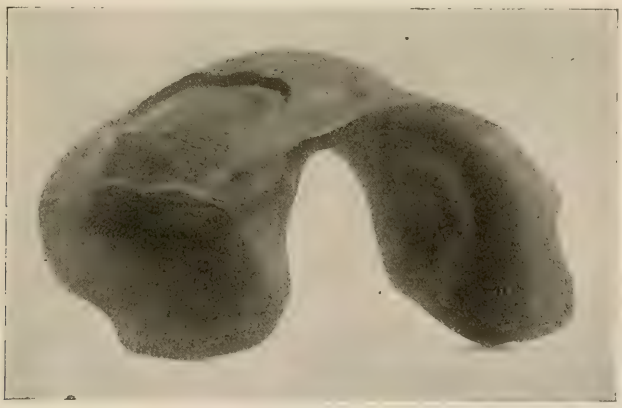


FIG. 539.—PLATE WORN AFTER REMOVAL OF BOTH UPPER JAWS.

be but little room to accommodate it. Fig. 538 shows a plate which is worn by a man whose upper jaw I removed. Although this "plumper" is small, there is scarcely a noticeable deformity, and mastication is accomplished satisfactorily on the sound side.

The greatest difficulty is experienced after removal of both upper jaws. Here it is imperative that the prosthesis should be inserted early, as contraction is rapid. Fig. 539 shows a plate which is worn by a man from whom I removed both upper jaws entire. This plate is much narrower than the normal mouth, but still gives a decided sense of tension. Such a device serves as a septum between the oral and the nasal cavities. It is held by the muscles of the cheeks, and may have some front teeth added for cosmetic effect. Such plates may be attached by springs to the back teeth of the lower jaw.

Prosthesis of the Lower Jaw.—The defect in the lower jaw usually requiring to be remedied is that which follows resection of half of the body. This operation is usually done when either the teeth are absent or the jaw is distorted by disease and an "impression" for reproduction cannot be made; however, the skillful dentist can take an "impression" of the mouth and judge the normal state of the diseased jaw from the upper teeth of the diseased side and from the lower teeth of the sound side. From this the prosthetic apparatus is made. Before the operation, an interdental rubber splint should be made, having a defect at the lower part representing the situation of the bone to be removed (Fig. 540). Food can be taken through this opening. This splint should be inserted as soon as possible after the operation, and the jaws bandaged together. The object of the splint is to keep the unopposed remaining half of the jaw from the inward displacement which will inevitably result without it. This splint is very important, and after

FIG. 540.—INTERDENTAL SPLINT TO BE WORN IMMEDIATELY AFTER REMOVAL OF HALF OF LOWER JAW.

A, opening corresponding to bone removed.

it is applied the ordinary bandage of the jaw should not be trusted, but adhesive strips should be incorporated in the bandage to make it secure and immovable. In a few days, after the traumatic irritation has subsided, the prosthetic "plumper" should be inserted. The device which has been found most serviceable for this purpose consists of a hard-rubber body, bearing teeth, and fitting the gap from which the bone was removed. It is attached at its inner end to a metallic shaft or plate which is fitted to lie against the inner surfaces of the remaining teeth of the other half of the jaw (Fig. 541). Offsets from this shaft fit into the spaces between the sound teeth to prevent backward and forward movement. The construction of this arm will vary in each case as the ingenuity of the dentist finds the best means of securing a fastening. Capping two teeth and constructing a bridge to which the arm can be articulated has proved practicable. A cap, fitting over a capped tooth in the lower jaw, and another cap over the back tooth in the upper jaw and connected to the prosthesis by a spring, have been successfully employed to hold the prosthesis in place. All such apparatus should be removable. If the ramus has been removed, the "plumper" should have added to it a short projection rounded at the top to partly take its place. This whole apparatus is smaller than the bone removed. A better final result is often secured by making an impression of the defect and constructing the "plumper" after this pattern. It is most expedient to make the first as a temporary

"plumper," without teeth, to be worn until the parts have become adapted to the new conditions, when a permanent one embodying the necessary modifications can be made. The important point is that it should be introduced as early as possible and not left out, for contraction which can not be overcome quickly takes place. It is also important that such apparatus should be easily removable for the sake of cleanliness. It is for this reason that, where the capping of teeth is resorted to, the apparatus should not be fixed to the permanent caps, but to caps which can be slipped over them. The artificial teeth are entirely cosmetic.

In cases in which a section of the jaw is removed, leaving teeth on either side of the defect, the prosthetic problem is a much easier one. Here the space is filled with a gold bridge, bearing a hard rubber body. After removal of the whole lower jaw the prosthetic apparatus must be attached to the back teeth of the upper jaw. Such an apparatus is constructed by mounting gold-plated springs upon caps on these teeth and joining the false jaw to springs.

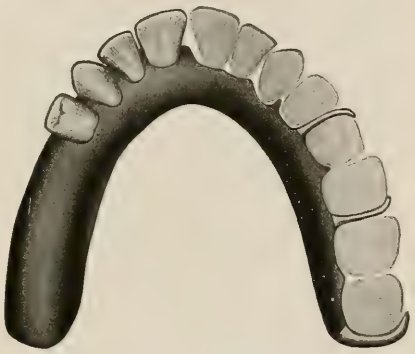


FIG. 541.—PROSTHESIS, CARRYING FOUR TEETH, INSERTED AFTER REMOVAL OF HALF OF THE LOWER JAW.

Excision and Resection of the Clavicle.—Excision of the clavicle is a serious operation because of the close proximity of this bone to the large vessels of the neck, their tributaries, and the cords of the brachial plexus. Behind and below the bone lie the innominate, subclavian, and jugular veins; the subclavian, suprascapular, and internal mammary arteries; the cords of the brachial plexus; the pneumogastric nerve; and the thoracic duct. The veins particularly, lying so close to the bone, are prone to become involved by the disease and require excision.

No rules can be laid down for excision for tumor, as the operation is proceeded with without reference to the bone. When excision for other disease is practised, it is desirable to perform a subperiosteal operation. An incision is made along the anterior margin of the bone, exposing the affected parts. The periosteum is divided in the same line. A short incision in the periosteum is made at right angles at each end of this incision. These periosteal flaps are turned up with the elevator and the separation continued as far as possible around the bone. The bone is then divided and the separation completed.

When the whole bone is to be removed for necrosis, the incision is continued beyond its extremities. The periosteum is divided in the same line and separated from the bone by the elevator. At the junction of the outer and middle thirds a wire-saw is carefully carried around the bone, or it is divided with the bone-cutting forceps. The inner end of the outer fragment is grasped by forceps and drawn forward, while it is cleared of periosteum posteriorly and below. This is removed, and the inner segment is dealt with in the same way. This sternal segment lies over the structures mentioned. Much care is advised in its removal. The elevator and knife should be kept close to the bone. The soft parts should not be dragged upon, and the vessels should be protected with a flat retractor. The wound should be closed, according to the rules laid down for the operative treat-

ment of osteomyelitis, and the arm put up as in fracture of the clavicle (see Subclavian Artery, page 413).

Excision and Resection of the Scappla.—Resection of parts of the scapula must meet the peculiar indications of each case; no rules can be laid down. Excision of the whole bone is done after the following method (Fig. 542, *A*): The patient lies on the sound side. An incision is made along the spine and the acromion process. This joins an incision made along the vertebral border, which need not be as long as the bone. The flaps are turned back, and the muscles attached to the spine and acromion are divided. The periosteum of the inner border is divided between the rhomboideus and the infraspinatus muscles, and the infraspinous fossa denuded of periosteum, carrying the muscle. If the marginal cartilage is not completely ossified, it should be left adherent to the periosteum. The supraspinous fossa is then cleared, care being taken not to injure the suprascapular nerve passing through the notch, but to raise it up with the periosteum. The lower angle of the bone is freed by detaching the teres major and serratus magnus, the bone is lifted away from the thorax, and the subscapularis dissected off from below upward. The denudation is continued and the bone is lifted away. If the disease permit, it is desirable to stop the denudation at the neck of the scapula, which is divided with the saw. If all of the processes have to be removed, the joint should be open from below and its ligaments divided. The acromion and coracoid processes are divided from their attachments and the bone removed. If possible, the coracoid process should be preserved by dividing it at its base and leaving it in place. The detached muscles and periosteum should be anchored in position with a few stay sutures.

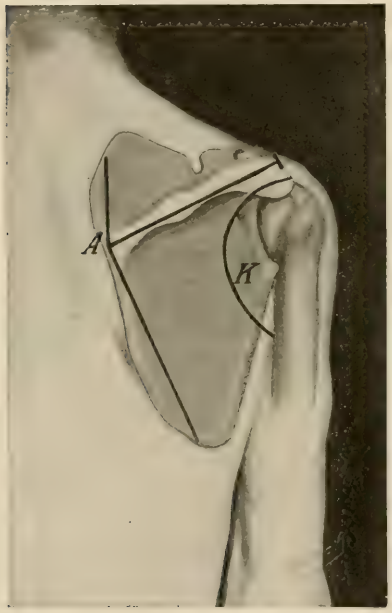


FIG. 542.—POSTERIOR VIEW OF SHOULDER.

A, Excision of scapula; *K*, posterior skin incision for excision of shoulder-joint. (*Kocher.*)

The operation may be reversed and the external attachments may be divided first and finally the vertebral borders freed. Or an incision along the spine of the scapula, another starting from the anterior extremity of this and running toward the root of the neck, and a third starting from the same point and running toward the axilla behind, may be made. Or two incisions, crossing near the center of the bone may be used. The vessels requiring attention are the posterior scapular, the suprascapular, and the subscapular arteries.

Resection of the Head of the Scapula.—When the head of the scapula is to be resected, without operation on the humerus, the operation is carried out through a posterior incision extending from the base of the acromion process downward to the posterior fold of the axilla.

Excision and Resection of the Humerus.—In operations upon the humerus it is most important to bear in mind the position of the musculospiral nerve, which traverses its upper and middle posterior surface obliquely

from above downward and outward between the external and internal heads of the triceps, and passes down the outer side at the lower third of the arm, between the brachialis anticus and the supinator longus.

Excision of the Head of the Humerus.—(See Excision of Shoulder-joint, page 741.)

Excision of the Shaft of the Humerus.—An incision is made along the posterior border of the deltoid and the outer edge of the biceps. The outer border of the brachialis anticus is discovered and followed down to the bone. The musculospiral nerve lies posterior to this, and it is wise to identify it and draw it aside. To prevent shortening some bone should be left, if possible; or the bone removed should be replaced by transplanted bone.

Excision of the Lower Extremity of the Humerus.—(See Excision of Elbow, page 742.)

Total excision of the humerus is accomplished through a combination of the incisions recommended for the other parts of the bone.

Excision and Resection of the Ulna.—This bone is quite superficial and easily removed. A longitudinal incision is made along its posterior aspect. At the upper end the incision should be made obliquely outward and upward between the triceps and anconeus muscles. Subperiosteal excision should be employed as far as possible. The triceps is retracted to the inner side and the olecranon freed. After the bone is exposed throughout, the operation is facilitated if it is divided in the middle and the halves removed separately. The posterior branch of the ulnar nerve passes back beneath the flexor carpi ulnaris about 6 cm. (2½ inches) above the lower end.

Excision and Resection of the Radius.—The incision in the skin is made from the styloid process of the radius, along the outer side of the forearms, to the radiohumeral articulation. The supinator longus is exposed at its posterior border and the bone is approached below, between it and the extensor tendons of the thumb, and above, between it and the two extensores carpi radiales. Coming down upon the supinator brevis, it is divided longitudinally, and the bone is exposed. The periosteum is opened and detached, the bone divided in the middle, and each half separately removed. For excision of a part of the bone, incision along this same line is used.

Excision of the Carpal Bones.—(See Excision of the Wrist, page 746.)

Excision and Resection of the Metacarpal Bones.—The metacarpal bones are best exposed by longitudinal dorsal incision over the bone to be excised. This incision should involve only the skin. The tendons and their sheaths crossing the bones should be drawn aside. The bone is exposed, its periosteum divided longitudinally, and stripped from the bone, the bone should be cut in two with forceps, and each half removed, care being taken not to open the joints. Good results may be secured if the metacarpophalangeal joint is not destroyed, and if long axis traction upon the finger is maintained to prevent its retraction upward. In most cases one or both ends of the bone may be saved. A transplant, taken from the tibia or elsewhere should be inserted into the defect.

Excision and Resection of Phalanges.—The incision should be made on one side or the other of the extensor tendons. In the case of a terminal phalanx the incision should be made more laterally, and pass around the end of the finger, close to the nail, in the shape of a U. If the periosteum can be preserved in the case of young persons and extension maintained, excision of the phalanges is indicated, but otherwise amputation is to be preferred, except in the case of the thumb, and here excision is always to be preferred, even though the periosteum cannot be preserved. Usually one or both ends of the bone may be saved. A transplant from the tibia or elsewhere

should be inserted into the defect (see Bone-grafting, page 786, Figs. 604 and 605). For methods of making traction see Fractures of Phalanges, page 580.

Resection of Vertebræ.—(See chapter on the Surgery of the Spine, Vol. II.)

Resection of the Bones of the Pelvis.—No rules for incision can be given for resection of the pelvic bones. Commonly but a portion of a bone requires removal, and this is best reached by incision over the disease. The whole of certain pelvic bones has been removed. Ollier removed the ascending ramus of the ischium and most of the pubic bone through an incision 10 cm. (4 inches) long, extending from the genitocrural fold toward the pubes. Excision of the whole ilium has been done with good results. For removal of the ilium the incision should follow the crest, and at the anterior-superior spine turn downward and backward toward the back of the great trochanter. The periosteum is divided along the crest and separated from the iliac fossa and externally. The separation may be carried as far as necessary and the bone removed.

Excision of the Coccyx.—This operation is done for coccygodynia for injury of the coccyx, to facilitate approach to the rectum, and for imperforate anus. An incision is carried in the median line from the tip of coccyx to its base, a finger in the rectum determining the exact position of the bone. In fat persons this incision may be supplemented by a transverse incision at its upper end. The bone is denuded posteriorly and laterally, the sacrococcygeal joint opened, the bone separated from the sacrum, the upper end grasped by the forceps, and the bone drawn out while its anterior attachments are divided.

Resection of the Femur.—Resection of a portion of the shaft of the femur is done for necrosis (see Operations for Osteomyelitis, page 692). The bone is best approached on the outer side through a longitudinal incision. The bone is reached between the vastus externus and the short head of the biceps. The muscles are strongly retracted, the periosteum stripped back as far as possible, and the desired segment removed. If there is no involucrum, a graft of bone should be inserted, and the limb treated as for fracture (see Bone-grafting, page 702).

Disease of the lower extremity of the femur, with sinuses in the popliteal region, is best reached by lateral incision passing down to the bone in the course of the intermuscular septum. The posterior aspect of the bone is easily reached in this manner, and the popliteal structures left posteriorly to the field of operation.

Excision of the Patella.—This operation may be done when the bone is the seat of destructive disease, when repeated fractures are associated with osteoporosis, or when the fractured patella is adherent to the femur and flexion and extension are much hampered. As much as possible of the continuation of the extensor tendon which lies in front of the bone should be preserved. This is best done by dissecting out the patella laterally through a longitudinal incision. The extensor tendon should be united to the patellar tendon. The posterior surface of the united tendon should be as smooth as possible. The best result is secured by dissecting up the synovial membrane which lies back of the extensor tendon, drawing it down behind the reconstructed tendon, and suturing it in place, with the view of covering the rough surface with synovial membrane. This latter feature of the operation is called for if the lack of relaxation does not permit direct union of the extensor tendon with the patellar tendon, but demands the use of the prepatellar portion of the tendon to fill the gap. It is surprising how well a patient gets along without the patella. The bone is essential neither for full flexion nor

extension. Instead of removing the patella for adhesion, a better operation consists in interposing soft tissue between it and the femur to prevent ankylosis.

The removal of the patella is better than a prolonged confinement in bed or treatment with an uncertain outcome. The bone is not essential for the function of the knee-joint. By suturing the quadriceps extensor tendon to the patellar tendon practically normal extension of the knee may be obtained. The important step is that the reflected synovial lining shall be united also beneath the site of the patella. Synovial lining for this purpose is to be found in the alar ligaments hanging at either side of the patella; and the reflected synovial membrane behind the quadriceps may be brought down.

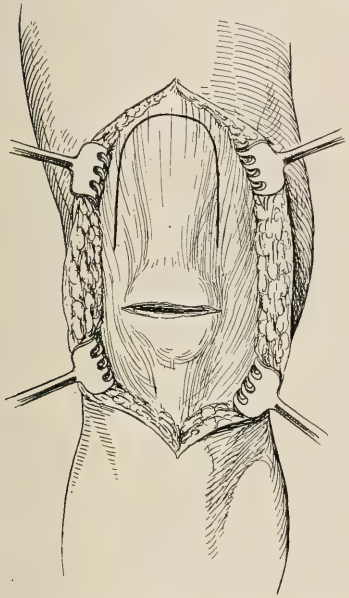


FIG. 543.—FLAP OF FASCIA TO BE TURNED DOWN TO STRENGTHEN PATELLA.

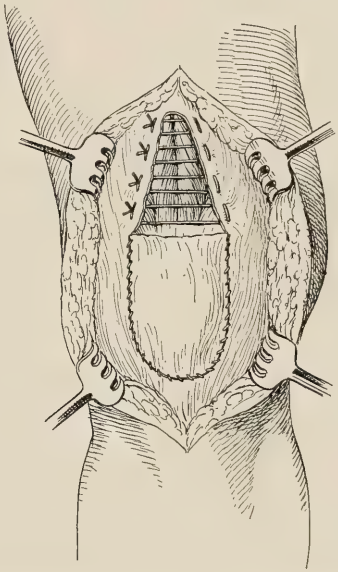


FIG. 544.—FLAP OF FASCIA TURNED DOWN TO STRENGTHEN PATELLA.

This operation is done for refracture and for weak patella. The fascia is sewed over the patella and the resulting defect partially sutured.

When tissue is required to strengthen the place of union between the quadriceps tendon and the patellar tendon, a flap of fascia may be turned down from the front of the thigh just above.

For Strengthening the Patella.—When operation is contemplated because of repeated refracture or inability to unite the fragments of a fractured patella, such a flap as above described, may be turned down and the resection rendered unnecessary (Figs. 543 and 544).

Excision and Resection of the Tibia.—This operation is done usually for necrosis following osteomyelitis or compound fracture. The location of sinuses should govern the place of approach, although it is most desirable to uncover the bone by a longitudinal incision just in front of its inner border, avoiding the internal saphenous nerve. When the posterior surface is to be reached, the incision should run along the inner border of the bone, and when the external surface is to be reached, the incision should be made just external

to the anterior border. The periosteum, having been divided longitudinally, should be elevated. As sound bone is approached above and below, in stripping back the periosteum, it is well to divide it transversely in order to save stripping it from the healthy part of the bone.

When a gap of less than 5 cm. (2 inches) exists after the removal of fragments following compound fracture, a similar length may be resected from the fibula. A much better procedure is to insert a bone graft (see Bone-grafting, page 701). If the gap is a larger one, an osteoplastic operation is the only operation to be considered.

Excision and Resection of the Fibula.—The fibula is subcutaneous at its upper and lower extremities; the shaft is covered with muscle. In excision of the upper end care should be taken not to wound the peroneal nerve or to open the tibiofibular joint, which usually communicates with the knee-joint. The nerve passes down along the posterior border of the tendon of the biceps, which is inserted into the head, and passes forward along the outer side of the neck of the bone. Before operating on the upper extremity of the bone it is well to locate and mark the position of the nerve before the patient is anesthetized.

Resection of the upper extremity of the fibula is done through a longitudinal incision, begun 2.5 cm. (1 inch) above the head, at the posterior border of the tendon of the biceps, and carried downward as far as necessary behind the bone in the space between the soleus and the peroneus longus muscles, with the view of leaving the peroneal nerve to the outer side. In removing the bone a shell bearing the articular surface may be left, in order to avoid opening the joint. In removal of the whole shaft of the fibula for disease the bone must be approached in two different planes of muscles, one above and one below, and divided in the middle, and each half removed separately. Resection of the lower end is described under Resection of the Ankle-joint.

Excision of the Tarsal Bones.—Excision of the bones of the foot for disease cannot often be done as a typical operation because of the peculiarities of each case. All the disease should be removed, all of the healthy bone should be left—is the principle to guide the surgeon. The character and extent of the operation must depend upon the nature of the disease and the age and condition of the patient. The bones most commonly requiring operation are the calcaneum and the astragalus. Subperiosteal excisions should be practised, if possible. It should be borne in mind that disease of these bones commonly starts in the calcaneum, then involves the calcaneo-astragaloid joint, and then the astragalus.

Excision and Resection of the Calcaneum.—Pains should be taken to leave all healthy bone and periosteum. In the subperiosteal operation (Fig. 564, *A*) the patient lies on the sound side and the inner side of the foot rests upon the sand pillow. The skin incision begins at the outer border of the tendo Achillis, about 2.5 cm. (1 inch) higher than the tip of the external malleolus. This incision is continued down along the outer border of the tendon below the outer tubercle of the calcaneum, around which it curves, and is then made to pass forward and slightly upward to the upper part of the base of the fifth metatarsal bone. The edge of the tendo Achillis and the plantar muscle are exposed. The bone is then uncovered in the line of the incision, care being taken not to divide the tendon of the peroneal muscles. This incision follows pretty closely the posterior and inferior contour of the bone. The periosteum is then elevated, carrying with it, if necessary, the tendo Achillis. The peroneal tendons are drawn aside, the external lateral ligament detached, and the exposure continued to the desired extent. If the whole bone is to be

removed, the calcaneocuboid and calcaneo-astragaloid joints are opened; the interosseous ligament is divided with a long straight bistoury. The bone is then grasped with the lion-jaw forceps and rotated downward, the calcaneo-astragaloid joint is further opened, and the internal lateral ligaments detached. The sheath of the flexor longus hallucis is opened in the operation.

Resection of the posterior portion of the bone is more simple. The incision is not carried so far forward, the periosteum is elevated, and the diseased segment cut out with the saw or chisel.

In the operation of Farabeuf (Fig. 545, *F*) the patient lies in the above-described position. An incision is carried from the base of the fifth metatarsal bone, on the outer border of the foot, backward and around the heel, and ends about 3 cm. (1¼ inches) to the inner side of the middle of the heel. This is met by a vertical incision, 5 cm. (2 inches) in length, just in front of the outer border of the tendo Achillis. These incisions are deepened and two

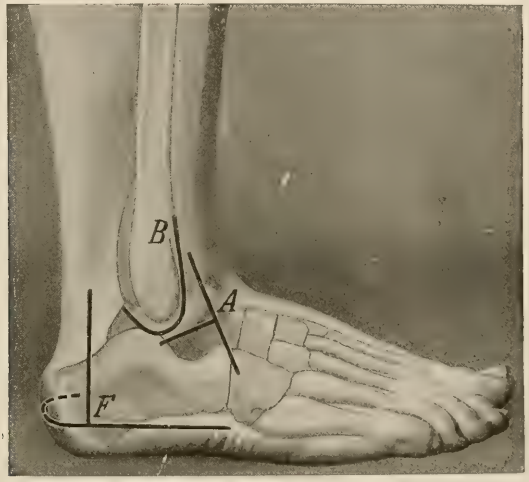


FIG. 545.—LINES OF SKIN INCISIONS AT OUTER SIDE OF FOOT AND ANKLE FOR RESECTIONS, AND EXCISIONS OF BONES.

A, Excision of astragalus, external incisions (see Fig. 546, *A*); *B*, excision of ankle-joint external incision (see Fig. 546, *B*); *F*, excision of calcaneum. (*Farabeuf.*)

flaps turned up, care being taken not to wound the peroneal tendons which lie under the anterior flap. The periosteum is incised vertically behind the peroneal tendons and horizontally in front of them. The periosteum with the attached ligaments is elevated from the bone as far as possible, including the tendo Achillis. By retracting the flaps most of the bone can be denuded, and the interosseous ligament divided. The anterior part is then grasped with lion-jaw forceps and abducted. As this is done the periosteum is elevated from the inner surface and the bone removed.

Excision of the Astragalus.—This operation is done for necrosis or caries, for paralytic club-foot, and as a step in excision of the ankle. It is no longer done for fracture and dislocation, unless necrosis makes it necessary. When removal of a fractured or dislocated segment of the bone is required, it is usually reached best over the most prominent part. Comminuted fragments may be reached through an incision between the extensor tendons of the first and second toes.

For complete removal of the bone the following operations are done

(Fig. 545, *A*; Fig. 546, *A*): The patient lies upon the back with the foot extending beyond the end of the table, or the lower third of the leg supported by the sand pillow. An outer incision 6 cm. (2½ inches) long is begun just above the lower articular margin of the fibula, and passes downward in front of the external malleolus, just posterior and parallel to the tendon of the peroneus tertius. To this incision is added another at right angles from its middle, which passes backward and downward and ends just below the tip of the outer malleolus. The two right-angle flaps are turned back and the bone is exposed between the tendons of the peroneus tertius and the peroneus brevis. The foot is then extended and inverted, the tendons retracted, and the ligaments connecting the bone to the tibia, fibula, calcaneum and scaphoid are divided as far as possible. An inner incision 5 cm. (2 inches) long is then made, beginning at the tip of the inner malleolus, and curved upward and forward just in front of the anterior margin of the malleolus. Through this incision the remaining ligaments holding the bone are divided.

FIG. 546.—LINES OF SKIN INCISIONS AT INNER SIDE OF FOOT AND ANKLE FOR RESECTIONS AND EXCISIONS OF BONES.

A, Excision of the astragalus, internal incision (see Fig. 545, *A*); *B*, excision of the ankle-joint, internal incision (see Fig. 545, *B*); *C*, excision of first metatarsal bone.

With the foot extended and inverted, the surgeon now grasps the bone through the outer wound with the lion-jaw forceps and wrenches it out. The neck of the bone may be sawed through and the head first removed.

The *anterior transverse incision* is the most simple (Fig. 564, *B*). It consists in a curved incision across the front of the ankle, beginning on the inner side at the point at which the tendon of the tibialis anticus crosses the tibiotarsal articulation, and passing forward to the middle of the scaphoid, and then back to just below the external malleolus. This flap is turned up, exposing the tendons, which are lifted out of their sheaths and retracted. The extensor brevis muscle is detached at its origin, the ligaments are divided, the foot inverted and the bone twisted out.

Excision of Astragalus and Calcaneum.—Osteoplastic excision of the heel and ankle was perfected by Mikulicz (Fig. 547). An incision is carried from a point just in front of the tubercle of the scaphoid bone transversely across the sole of the foot to a point just behind the fifth metatarsal bone.

From each end of this incision incisions are carried upward and backward to points just above the two malleoli. These two last incisions are joined at their upper ends by a transverse incision passing around the back of the ankle. All of these cuts are carried down to the bone. The lateral ligaments of the ankle are then divided, and the calcaneum and astragalus dissected out. The malleoli with the articular surface of the tibia are then sawed off transversely, and likewise the posterior articular surfaces of the cuboid and scaphoid bones. The cut surfaces of the two tarsal bones are then brought up into apposition with the cut surfaces of the leg bones and sutured. As a result of this operation the weight of the body is borne upon the distal ends of the metatarsal bones, the toes being extended.

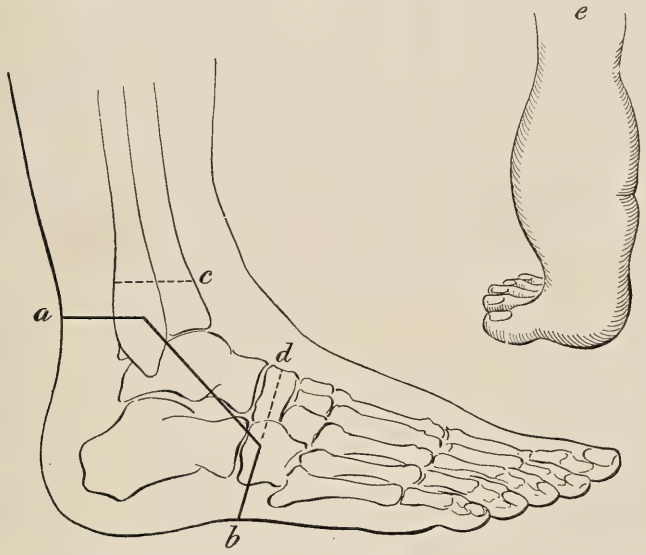


FIG. 547.—OSTEOPLASTIC EXCISION OF THE HEEL AND ANKLE. (*Mikulicz.*)
ab, Skin incision; *c* and *d*, lines of the division of the bones; *e*, postoperative result.

Excision of Metatarsal Bones.—The incisions for removal of these bones correspond to those employed in the hand. Every effort should be made to preserve the anterior extremity of the first metatarsal bone, as it constitutes the main anterior support of the arch of the foot. Likewise the importance of the great toe in walking should be remembered.

OPERATIONS ON JOINTS

In all operations on joints, in which it is desired to retain the synovial lining in good functionating condition, as little traumatism as possible should be inflicted. Pressing sponges in a joint, rubbing the synovial surfaces with gauze, and traumatizing it with instruments, are all to be deprecated if it is desired to prevent adhesions and stiffness, as the joint-linings are very sensitive to such insults. Permanent ankylosis may follow the rough sponging of a sterile joint. A certain amount of stiffness follows the simplest opening of a joint. This is one reason why the results in many simple operations are misinterpreted. After removal of semilunar cartilages from the knee, or operations on the crucial ligaments, the stiffness which follows gives a sense of strongness in a previously weak joint, and the patient reports improvement. But after a few months when normal flexibility has returned, the joint is often worse than it was before.

Exposure, Excision, Resection, Arthrodesis and Erasion of Joints

"Complete excision" of a joint means the removal of the articular ends of the bones which enter into the composition of the joint. "Partial excision" means the removal of the articular surfaces of one or more, but not all, of the principal bones entering into the joint. The term "resection" is applied to the removal of the entire thickness of a bone. Excision of joints is done for destructive disease, infective disease (to stop its progress), old unreduced dislocations, ankylosis in faulty position, and to secure greater mobility in stiff or ankylosed joints. Erasion or arthrectomy means removal of the synovial membrane, and is practised in intractable infective synovitides and in the early stages of many of the diseases for which excision may be required (see Arthrectomy, p. 710). Excisions in children, removing the epiphysis, stop the normal growth of the limb. Fortunately, this operation for inflammatory disease has been much superseded in the last few years by more conservative measures. For adults, too, the operative treatment of chronic inflammatory diseases of joints has been minimized by the application of the newer general and local measures for treating tuberculosis. These advances in surgery, together with the improvements in the treatment of fractures and dislocations and in the employment of arthrectomy, have made less frequent the systematic resections and excisions once practised so freely in the early days of the antiseptic era.

In excisions the main blood-vessels and nerves must carefully be guarded. When excision is done to secure ankylosis, the division of tendons and muscles is of little moment, but when mobility is hoped for, the conservation of these structures is imperative. The division of a tendon or muscle which is to be preserved should be made obliquely to facilitate its subsequent suturing. In sawing off the articular end of a bone, it is well to make a "conservative section;" that is, to remove as little as possible, and then use the curet or gouge to complete the eradication of the disease.

The total extirpation of joints without opening the synovial sac can be practised with success in the case of the knee-, ankle-, elbow-, and shoulder-joints, and the smaller joints of the hand and foot. The operation has little to recommend it, and presents the decided objection of removing the joint without an opportunity of previously inspecting it.

Arthrodesis (the artificial production of ankylosis) is practised chiefly upon the hip- and ankle-joints to improve the usefulness of the lower extremity in cases of paralytic relaxation and loss of control of the joint. It is employed in the treatment of paralytic hip-joint luxation. It is of special service in permanent paralysis of the leg muscles controlling the ankles. The operation consists in opening the joint by means of the incisions described for excision of joints, thoroughly curetting the articular cartilages, applying tincture of iodin or pure liquid phenol to all of the articular and synovial surfaces, washing out with alcohol, closing the wounds without drainage, and immobilizing in the desired position. The immobilization should be complete and continue for six to eight weeks. In some joints it is better to remove a section of the articular surface instead of practising the above irritant treatment.

This operation should not be done in children under eight years of age. The epiphysis should not be injured; and all the improvement and correction possible by treatment of the muscles and nerves should have been secured. So long as there is hope of muscular recovery the operation should not be done.

Arthrodesis in infantile paralysis is most commonly called for to rectify the talipes valgus or varus at the astragaloscaphoid, calcaneo-astragaloid,

or both of these joints. The astragalus is usually found securely enough held between the two malleoli to require no operation at the ankle-joint. If the tibio-astragaloid articulation is badly relaxed, a better result will be secured by removing the astragalus. Arthrodesis between the first-mentioned joints gives marked relief.

In *intractable flat-foot*, which has resisted all other treatments, arthrodesis between the astragalus and scaphoid gives a firm restoration of the arch.

In *hammer toe* the operation is most effective.

In *wrist-drop*, from irremediable paralysis of the extensors, arthrodesis done between the radius, scaphoid and semilunar bones, fixing the wrist in the straight position, gives a more powerful use of the flexor muscles and a better appearance of the hand.

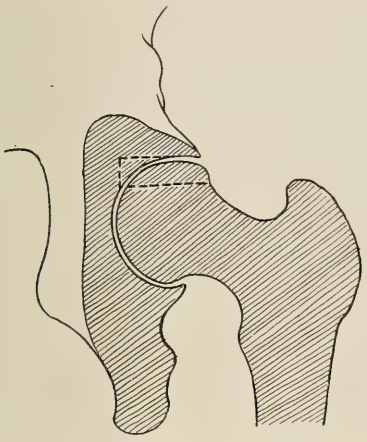


FIG. 548.—OPERATION FOR PRODUCING SOLID ANKYLOSIS OF HIP-JOINT.

The upper part of the head of the femur and the wall of the acetabulum are to be removed with chisel and curet. (*After Albee.*)

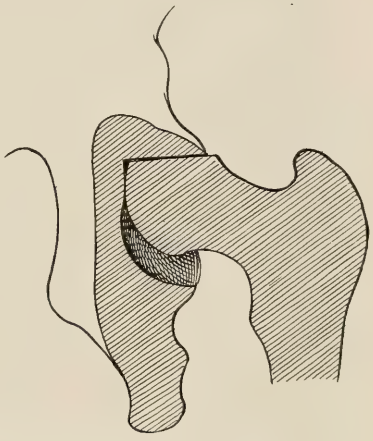


FIG. 549.—OPERATION FOR SECURING SOLID ANKYLOSIS OF HIP-JOINT.

Bone has been removed from head and acetabulum. Note that head rides upward out of socket and some shortening results. (*After Albee.*)

In *osteo-arthritis* and *paralytic relaxation of the hip* the joint may be reached by an anterior incision. The capsule is opened. One-third of the upper part of the head of the femur is removed with a thin chisel. The roof of the acetabulum is converted into a flat surface by means of a chisel and curette. The limb is immobilized in a plaster-of-Paris splint from the chest to the toes. The bone should be removed so as to give slight abduction (Figs. 548 and 549).

For Stiffening the Knee-joint.—Relaxed knee-joints, with loss of control, especially those due to infantile paralysis, have been stiffened by resection; but this has the disadvantage that it gives shortening. A better procedure is by a transverse incision just below the patella, the patellar ligament is divided, and the patella turned upward; the bone is then denuded of cartilage and the front of the femur and tibia similarly treated, thus making a bed to receive the patella. The crucial ligaments and the epiphyseal lines should not be harmed. The joint surfaces are irritated by scraping and applying iodin, and the bone fitted into its bed. The patellar ligament is sewed and the wound closed. A plaster-of-Paris splint is applied, and in four to six weeks the patient is allowed to walk. All support is removed by the

end of the fifth to the seventh month. The patella becomes united to the femur and the tibia.

Exposure of the Temporomaxillary Joint by Resection of the Zygoma.—The exposure of the temporomaxillary joint has usually been accomplished by a vertical incision through the soft parts, extending from the zygoma to the facial nerve. This does not give a really free access, and always endangers the facial nerve. H. Lilienthal devised a temporary resection of the zygoma. He made a horizontal incision along the zygoma, extending back to a point in front of the auricle, and thence a vertical incision is carried

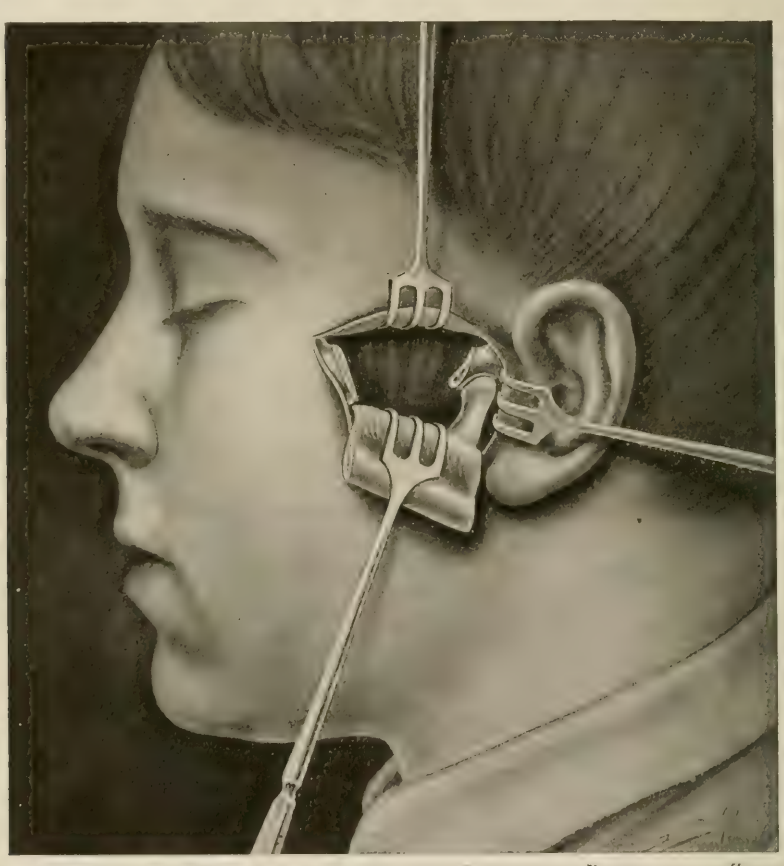


FIG. 550.—ACCESS TO TEMPOROMAXILLARY JOINT SECURED BY RESECTION OF ZYGOMA AFTER METHOD OF LILIENTHAL.

down in front of the ear toward the angle of the jaw. The horizontal incision passes down to the periosteum of the zygoma; the vertical incision is about 4 cm. (1½ inches) long, and passes only through the skin, avoiding the subcutaneous structures. The triangular skin-flap is dissected free and retracted downward and forward. This exposes the zygoma. By means of the wire saw, passed under the arch, the zygoma is divided in two places, anteriorly and posteriorly. This division of the bone Lilienthal makes obliquely to the long axis of the zygoma, the anterior section passing upward and forward, and the posterior section passing upward and backward, so that when the segment is pressed back into position it can not be drawn

down by the masseter. The resected zygoma is then retracted downward, carrying with it the attachment of the masseter muscle, the upper end of the parotid gland, fibres of the facial nerve, and connective tissue. This exposes the temporomaxillary articulation (Fig. 550).

The degenerated head and neck of the inferior maxilla in cases of bilaterial ankylosis may be removed with gouge and curette, by operating first upon one side and then upon the other after an interval of a few days. Upon replacing the resected segments of zygoma, they may be held firmly in place by the contraction of the masseter, and require no suture.

Excision of the Shoulder-joint.—This operation is usually a partial excision, as only the head of the humerus is removed. Removal of the head of the scapula is rarely required; when diseased, it can usually be treated with the gouge or curette. Arthroplasty for the interposition of a flap of soft tissue may be done at the original operation or later (see page 761).

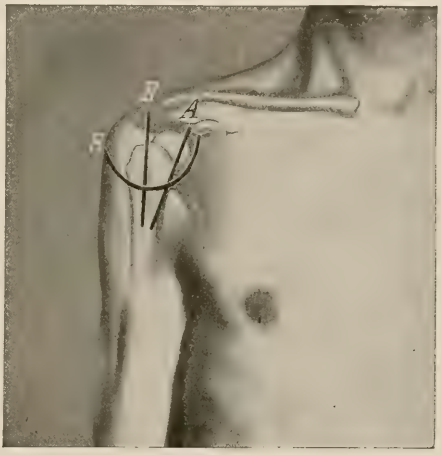


FIG. 551.—ANTERIOR INCISIONS USED IN EXCISION OF SHOULDER JOINT.

A, Anterior incision (*Ollier*); *B*, vertical incision (*Langenbeck*); *S*, curved incision for osteoplastic excision (*Senn*).

Excision through an Anterior Incision (Fig. 551, *A*).—The patient lies upon his back close to the edge of the table with the shoulder somewhat raised. The arm is slightly abducted. The surgeon stands facing the patient, the first assistant stands above the shoulder, beside the patient's head, facing the operator. An incision 10 cm. (4 inches) long commences at the outer side of the tip of the coracoid process and is carried downward and slightly outward, following the direction of the anterior margin of the deltoid muscle. This incision is carried down to the joint. The capsular ligament is opened just to the outer side of the tendon of the long head of the biceps, and the incision carried down to the humerus. The periosteum and capsular ligaments are then elevated from this line outward as far as possible while an assistant rotates the arm inward. The periosteum, bearing the insertion of muscles into the greater tuberosity, is separated. The tendon of the biceps is then lifted out of the way, the arm rotated outward, and the periosteum and capsule elevated toward the axilla. The insertion of the subscapularis is elevated or dissected off with the periosteum. If the tuberosities are not diseased, the tendinous insertions may be more surely preserved by elevating a thin shell of bone with the periosteum by means of the chisel. The head of the humerus is then dislocated forward through the wound, the elevation of periosteum from the posterior surface completed, and the head of the bone sawed off. Any disease of the glenoid fossa is dealt with. Drainage, if necessary, is secured through a small opening made posteriorly.

If this subperiosteal operation cannot be done, the muscles are simply divided from the bone without preserving their attachments. If only the articular head is to be removed, the division can be made at the anatomic

neck with the key-hole saw, wire saw or chisel, without lifting the bone out of the wound. Early and persistent passive motion should be practised.

Excision by the Deltoid Flap.—The incision begins just below the tip of the acromion process, passes downward and curves outward across the arm about 10 cm. (2 inches) below the top of the lesser tuberosity, then backward and upward to the top of the greater tuberosity. This operation has the great disadvantage that it divides the deltoid muscle, which, however, can be sutured. Its advantage is that it gives a free approach to the joint.

Excision through a Vertical Incision (Fig. 551, *B*).—The arm being rotated inward, the incision begins above at the anterior border of the acromion, just outside of the acromioclavicular joint, and passes downward about 10 cm. (4 inches) in the line of the bicipital groove. The incision is carried down through the deltoid muscle to the tendon of the biceps. The sheath is split, the tendon retracted, and the joint opened through the sheath. The periosteum and capsule are elevated, first on the inner side and then on the outer side, the knife being used to separate these structures from the bone over the tuberosities. The operation is proceeded with as through the *anterior incision*. This incision has little to recommend it, as it destroys some of the nerve-fibres to the deltoid and approaches the joint through the thickness of the muscle.

Excision by a Transverse Incision.—An incision 9 cm. (3½ inches) long is made 1.25 cm. (½ inch) below the edge of the acromion and parallel to it, having its anterior end between the acromion and coracoid processes. The deltoid is divided through this incision and the joint freely exposed. The capsule is opened along the outer side of the biceps tendon and also transversely.

Excision by Division of the Acromion through a Posterior Incision (Fig. 542, *K*).—Kocher carried a curved incision from the acromioclavicular joint (which he opened) backward over the shoulder, along the acromion to its root, severing the trapezius, and from there downward to the posterior fold of the axilla, ending about 4.5 cm. (1¾ inches) above the lower border of the deltoid. The infraspinatus and supraspinatus muscles are separated from the acromion, and the process divided at its junction with the spinous process. The acromion with its attached deltoid is pressed over the head of the humerus. The joint is then opened along the line of the bicipital tendon. The tendon is retracted forward and the external rotators retracted backward. This exposes the head of the bone for such treatment as may be required. The acromion is sutured back in place.

Excision by a Curved Osteoplastic Incision (Fig. 551, *S*).—An incision is begun at the coracoid process, curved gently downward and outward below the greater tuberosity, thence curving upward and backward the same distance, ends at the spine of the scapula. The semilunar flap thus formed is dissected up so as to expose well the acromion. The saw is applied, the acromion divided, and the fragment reflected downward with its deltoid connection. The capsule of the joint is opened and the disease dealt with. The operation is completed by suturing the acromion back in place with chromic gut sutures and closing the wound with or without drainage.

Excision of the Elbow-joint.—One of two results should be aimed for in this operation: the most useful possible movable joint, or ankylosis in flexion at an angle of 135 degrees. While the former result should be striven for, ankylosis is preferable to a very loose joint. Complete excision is usually performed. In typical excision the humerus is sawn through at the epicondyles, the ulna at the base of the coronoid process, and the radius at its neck. More than this must often be removed. Whenever possible all of the olecra-

non except its articular surface should be saved. When this can be done, the strong extensor attachment of the triceps is retained. It is also most important to retain the attachment of the brachialis anticus to the ulna and the bicipital attachment of the radius. The posterior aspect of the joint is superficial, the important vessels and nerves, excepting the ulnar nerve, all lying anteriorly. The ulnar nerve, which passes behind the internal condyle, lies along the inner side of the olecranon. Excision through the H-incision has been superseded by the method of the simple lateral incision on the radial side. After excision, if a movable joint is aimed for, the arm should be put up on a splint with the elbow flexed at an angle of 135 degrees; that is, an angle midway between complete extension and right-angle flexion. The forearm should be midway between pronation and supination, the thumb directed upward. Passive motion should be begun in about a week after operation if a soft tissue flap has not been interposed between the bones.

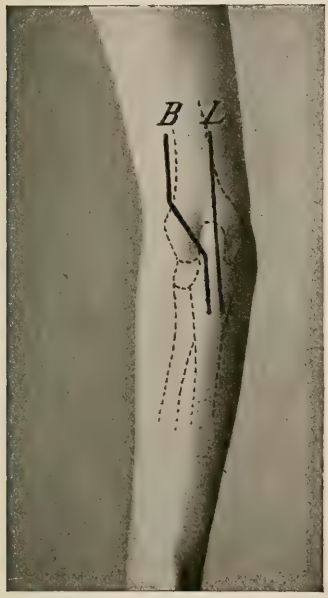


FIG. 552.—INCISIONS FOR EXCISION OF ELBOW-JOINT.

B, Radial incision; *L*, median incision.

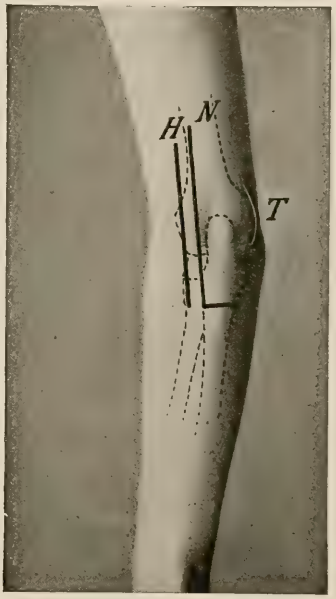


FIG. 553.—INCISIONS FOR EXCISION OF ELBOW-JOINT.

N, Right angular incision; *H*, *T*, long external and short internal incision.

In most cases of resection of the elbow a movable joint should be aimed for. It is best secured by arthroplastic operation in which soft tissue is interposed between the bones. This may be done at the time of the resection or excision or as a subsequent operation (see Arthroplasty, page 762).

Excision by the Radial Incision (Fig. 552, *B*).—This is called the "bayonet incision." The patient lies upon the back close to the edge of the table. The upper arm should be held in a vertical position, the forearm slightly flexed and carried across the patient's chest. In operating on the right arm the surgeon should stand by the patient's loins, and in operating on the left arm he should stand a little away from the patient's side. An incision is begun 5 cm. (2 inches) above the upper end of the olecranon process on the outer side of the arm opposite the space between the supinator longus and the

triceps; that is, about 3 cm. (1¼ inches) above the external epicondyle. The incision is carried directly downward, parallel with the long axis of the humerus, to the epicondyle; thence downward and inward to the middle of the outer side of the olecranon; and thence again downward over the back of the olecranon and shaft for 2.5 to 5 cm. (1 or 2 inches). This is a skin incision, but over the ulna it goes down to the bone. The capsule of the joint is exposed by separating the triceps on the inner side and the supinator longus, extensor radialis longior, and anconeus on the outer side. The capsule is opened, the lower end of the humerus exposed, and the periosteum and capsular ligament divided about the outer edge of the articular surface and the muscular attachments elevated with the periosteal elevator. The periosteum of the ulna, carrying with it the tendon of the triceps, is next elevated, beginning at the outer edge of the articular surface. The external tuberosity of the humerus and the condyle are next denuded, the periosteum carrying with it the muscular and ligamentous attachments. The joint is then flexed, the lower end of the humerus dislocated into the wound, the separation of periosteum completed, and the lower end of the bone sawn off from one epicondyle to the other. The head of the radius is removed, and, after the completion of the denudation of the ulna, the upper end is sawn transversely through.

Excision by the Posterior Median Incision (Fig. 552, *L*).—The patient lies as in the above operation. A skin incision about 10 cm. (4 inches) long, crossing the back of the joint, is made in the direction of the long axis of the forearm, beginning 5 cm. (2 inches) below the top of the olecranon, following the posterior border of the ulna and passing upward across the center of the olecranon depression of the humerus. The knife bisects the triceps tendon and passes directly down to the bone. The joint is opened in the same line and the parts retracted. First the inner half of the triceps tendon is elevated with the periosteum from the olecranon. The periosteum is then divided at the inner side of the articular surface of the humerus and the inner condyle is cleared. If the elevator is kept close to the bone, the periosteum with the attached muscles may be lifted away from the bone and the ulnar nerve not injured. The internal lateral ligaments are also detached in the same way. The same process is applied to the outer side. When the outer condyle is reached, strong retraction is necessary, and care must be given to keep close to the bone lest the posterior interosseous nerve be injured. The joint is now strongly flexed, the lower end of the humerus extruded through the wound, cleared of its attachments as high as is necessary, the articular surface grasped with lion-jaw forceps, and sawed through transversely just below the tips of the epicondyles. With the joint in the same position the upper ends of the ulna and radius are made to protrude through the wound, the soft parts are retracted, and the upper end of the ulna sawed off horizontally, carrying with it all of the articular surface and leaving as much of the coronoid process as possible. The upper end of the radius is sawed off at the same time.

Excision by a Right Angular Incision (Fig. 553, *N*).—A longitudinal incision 7.5 cm. (3 inches) long is made on the outer side of the joint, beginning on the outer side of the humerus about 4 cm. (1½ inches) above the tip of the olecranon, and carried down behind the outer condyle to a point just posterior to the neck of the radius. From the lower end of this incision a second cut is carried inward at a right angle across the back of the ulna. The triangular flap, including the periosteum of the ulna, is dissected up. Kocher made this incision in a J-curve. The external ligaments are divided and the head of the radius is removed. The denudation of the ulna is com-

pleted and the bone sawed across. The humerus is projected through the wound and treated as above described. This operation can only be recommended when the periosteum of the ulna is not divided transversely, but along the outer border of the olecranon, and elevated with the tendon of the triceps, as in the first operation described.

Excision by Long External and Short Internal Incisions (Fig. 553, *H*, *T*).—A longitudinal incision, 1.25 cm. (½ inch long), is carried down upon the front of the internal epicondyle, and the muscles and internal lateral ligament are separated from the bone. An incision about 6 or 8 cm. (2½ or 3 inches) long is then made behind the external epicondyle, ending below at the outer side at the head of the radius. The external lateral ligament is divided and the joint is opened in this line. The head of the radius is removed. The lower end of the humerus is denuded, as described above, and removed, and likewise the upper end of the ulna.

The H-*incision* was formerly used when the triceps tendon was cut through. This is now rarely done.

Fig. 554.—Posterior Curved Incision for Exposure of Elbow-joint.

Partial excision is indicated when only a part of the articular surfaces requires to be removed. When only the lower end of the humerus is to be resected, the radial incision or the external and internal incision is indicated. The articular surfaces of the radius and ulna are best exposed by the median incision or the lower part of the radial incision.

Osteoplastic Excision.—For exposing the joint for the treatment of ankylosis, fungous arthritis, old or irreducible dislocations, and foreign bodies, transverse division of the olecranon process is often of much service. This operation is best done through the external incision, which may be modified to suit the requirements of the case. The skin is retracted from the olecranon, and this process divided at its base and turned up. This exposure permits a free exhibition of the joint. The end of the humerus or radius may be removed and the articular surfaces of the ulna dealt with. Conditions within the joint are rendered most accessible. If desirable, a transverse skin incision may be added, giving still more exposure. The operation is completed by suturing the olecranon back in place just as is done for fracture.

Excision of the Elbow for Ankylosis.—This operation is indicated to secure a better position in cases of faulty bony ankylosis. The bone can best be exposed by the long posterior incision. The periosteum should be elevated and the ulna divided. The periosteum and capsule are detached, and the lower ends of the humerus and, if necessary, the radius and ulna sawed off. This operation may be carried out through the radial incision by the osteoplastic method. The operation may be still more simplified by exposing the

joint through a posterior H-incision, dividing the olecranon, and then with knife and chisel dividing the ankylosing structures in the joint. The interposition of a flap of soft tissue may then be done, and the wound closed. After operation the elbow should be put up at an angle of 135 degrees.

The posterior curved incision (Fig. 554) has decided advantages in cases in which exposure of the joint is to be made for ankylosis or other non-infective condition. It is made in the form of an inverted U. The ends of the incision rest just below the condyles, and the top of the bow is 5 cm. (2 inches) above the olecranon. A flap of skin is turned down. The ulnar nerve is isolated and drawn aside. A transverse incision is carried across the back of the joint, dividing capsule and soft tissues covering the olecranon. The olecranon is sawed in this line, the joint flexed, and exposed. After resection or arthroplasty the capsule is sutured, and the olecranon united.

FIG. 555.—POSTERIOR INCISIONS FOR EXCISION OF WRIST-JOINT.

A, *B*. Two dorsal incisions (*Ollier*); *C*, single dorsal incision (*Boeckel*); *D*, *E*, bilateral incisions (*Lister*); *B*, *D*, internal and external dorsal incisions (combination of incisions of Ollier and Lister).

Excision of the Wrist.—This operation is done for disease of the carpal bones, and, as the disease commonly involves the lower end of the radius and the upper ends of the metacarpal bones, excision of the articular surfaces also becomes a part of the operation. The wrist bones are best approached in the triangular space between the extensor tendons of the thumb and index-finger. At this place are no important structures and free access to the wrist is secured. As in other parts, it should be borne in mind that a typical operation should not be aimed at. The surgeon should preserve the bones which are free from disease. This is particularly important in the case of the trapezium which supports the thumb. The operation of complete excision is best performed by an outer and inner dorsal incision combined. After any of these operations the hand and forearm should be put upon a splint and passive motion should be applied to the fingers early. The splint must be worn for two months or more until the parts have become adjusted, if arthroplasty has not been done.

Excision by Two Dorsal Incisions (Fig. 555, *A*, *B*).—The patient's hand, dorsum upward, is placed upon a small table at the side of the operating table. The radial incision begins over the lower border of the lower extremity of the radius, midway between the two styloid processes, and is carried obliquely downward to the outer side of the middle of the second metacarpal bone. For convenience in reflecting the soft parts the upper end of this incision may be extended inward 4 cm. (1½ inches) further. The tendon of the extensor indicis is retracted outward and the metacarpal bones ex-

posed. Care should be taken not to divide the dorsal branch of the radial nerve. The wrist-joint is opened and the posterior annular ligament divided. The ulnar incision is next made. It begins at a point 3 cm. (1¼ inches) above the tip of the styloid process of the ulna and passes downward to the base of the fifth metacarpal bone. It passes along the outer side of the tendon of the extensor carpi ulnaris. This incision is carried down to the bone, exposing the ulna, the cuneiform, and the unciform. Care should be taken to avoid cutting the dorsal branch of the ulnar nerve to the little finger. The removal of the carpus is accomplished by stripping the bones of their ligaments and periosteum, and lifting them out with the curet or forceps. The bones are removed through whichever incision renders them most accessible.

The removal of the ends of the radius and ulna is accomplished by making them protrude through the wound, stripping back the periosteum, and sawing off the diseased articular surfaces. If the disease is not extensive, it may be removed by the gouge or curet. The removal of the proximal ends of the metacarpal bones, if necessary, is accomplished in the same manner. Drainage-tubes are inserted and the hand put upon a splint according to the indications.

Excision by a Single Dorsal Incision (Fig. 555, *C*).—This incision is placed in the interval between the extensor indicis and the extensor secundi internodii pollicis, following closely the outer border of the former of these tendons. It is about 10 cm. (4 inches) long, and begins 4 cm. (1½ inches) above the joint line over the lower end of the radius, and ends over the middle of the second metacarpal bone. The dorsal structures are dissected up by overextending the wrist, thus relaxing the extensor tendons. Through this incision a subperiosteal operation is done, but not so easily as with the two lateral dorsal incisions.

Excision Through Bilateral Incisions (Fig. 555, *D*, *E*).—The radial incision begins above at the middle of the lower extremity of the radius at a level with the base of the styloid process. It passes downward and outward, parallel with the tendon of the extensor longus pollicis, to the inner side of the first carpometacarpal articulation, and thence directly downward along the outer side of the second metacarpal bone for half the length of the bone. This incision is about 10 cm. (4 inches) long, and placed so as to avoid the radial artery. It should pass down to the bone and sever the tendons of the extensor carpi radialis longior and brevior at their insertions, but not the tendons of the thumb. The soft structures on the ulnar side of the incision are then dissected up, the wrist being strongly extended. The long and short extensors of the wrist are divided. The trapezium is separated and left for the last, if its removal is necessary.

The ulnar incision is begun 5 cm. (2 inches) above the lower end of the ulna on its anterior aspect, and passes downward between the bone and the tendon of the flexor carpi ulnaris as far as the middle of the palmar side of the fifth metacarpal bone. The inner side of the wound is retracted, and the tendon of the extensor carpi ulnaris cut at its insertion. The wrist is then strongly extended and the soft structures dissected away from the bones. The posterior ligaments are divided, and the joint opened. The connection of the tendons with the radius is left undisturbed. The carpal bones are easily removed through these incisions, and the ends of the radius and ulna and metacarpal bones given the necessary attention. The trapezium is examined last, care being taken to avoid injury to the tendon of the flexor carpi radialis and to the radial artery. The non-articular parts of the pisiform and unciform bone should be left, if sound.

Excision of the Hip-joint.—This operation is done usually for disease of the head of the femur, and is, therefore, an incomplete excision. When the joint is exposed, any other foci of disease are to be dealt with as the case may require. The acetabulum may be diseased, and necrotic pieces of bone required to be lifted out or carious foci gouged or curetted. The operation is simple, and the only condition which presents a difficulty is the presence of the heavy muscles by which the joint is surrounded. The joint is best exposed by the external incision. Extension by weight or elastic traction in bed or with the Thomas splint should follow the operation. Arthroplasty for the interposition of a flap of soft tissue may be done at the time the resection is performed or as a subsequent operation (see Arthroplasty, page 765).

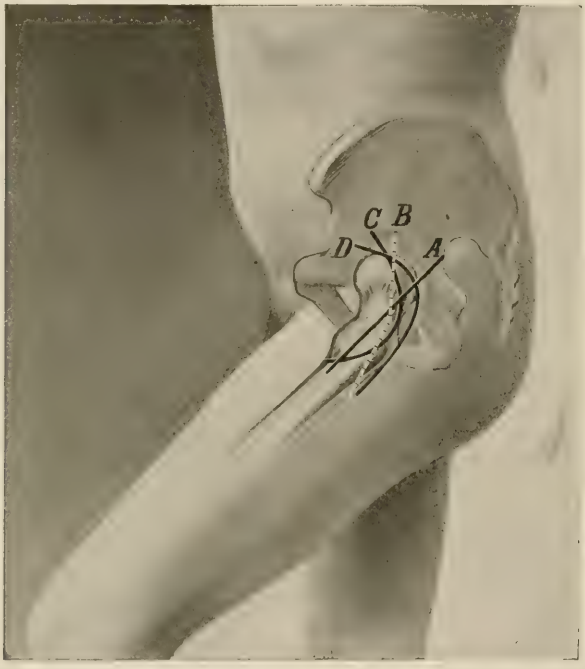


FIG. 556.—EXTERNAL INCISIONS FOR EXCISION OF HIP-JOINT.
A, Straight incision (*Langenbeck*); *B*, curved incision (*Ollier*); *C*, bow incision (*Sayre*); *D*, right angular curved incision (*White*).

Excision of the Hip-joint by a Straight External Incision (Fig. 556, *A*).—The patient lies upon the sound side; the diseased thigh is flexed at an angle of 45 degrees, and rotated slightly outward. A straight incision 12 cm. (4½ inches) long is made in the direction of the long axis of the femur. It should lie a little behind the middle of the great trochanter. Two-thirds of the length of the incision should be above the trochanter and one-third of the incision should lie on the femur. The upper end of the incision will thus lie about opposite the great sciatic notch. The knife above the trochanter is carried down to the muscle, the fibers of which are separated down to the joint and, below, the incision is made down to the bone. The muscle is retracted and the capsule of the joint opened in the direction with the line of incision. The capsular ligament is also divided transversely close to the acetabulum. The muscles inserted into the great trochanter are divided at

the insertion. If the ligamentum teres has not been destroyed by disease, it must be divided. The thigh is now rotated inward and the head of the bone is dislocated backward and thrust out of the wound. The soft parts are protected by retractors, and the diseased upper end of the bone sawed off. Free access to the acetabulum is thus secured. Further diseased bone is gouged or curetted, sinuses followed up, and diseased synovial membrane removed. A drainage-tube may be left in the wound for a few days. The joint should be immobilized by a Thomas hip splint, a long side splint, or a light plaster-of-Paris case, with a few pounds of longitudinal traction.

Excision of the Hip by a Curved Incision.—A curved incision (Fig. 556, *B*), beginning 8 cm. (3 inches) below the crest of the ilium and the same distance behind the anterior superior spine, passes downward to the great trochanter, and thence down the shaft of the femur, uncovering the bone. Its length should be about 13 cm. (5 inches). The superficial fascia being retracted, the gluteus maximus will be found posterior to the incision. The fibers of the gluteus medius and the gluteus minimus are separated in the line of the incision, and the capsule of the joint exposed without dividing the muscle.

The bow incision is still more sharply curved (Fig. 556, *C*). Beginning midway between the anterior superior spine of the ilium and the top of the great trochanter, passing in a gentle bow down across the trochanter, midway between its middle and posterior border, and thence bowing forward and downward, it ends just above the level of the lesser trochanter, and is about 15 cm. (6 inches) long. Throughout its whole length the knife is carried down to the bone and through the periosteum. The soft parts are retracted, the periosteum is divided transversely just above the level of the lesser trochanter, the division being carried around the bone as far as possible. The two flaps of periosteum are stripped up, beginning at the junction of the two incisions. At the digital fossa the muscular insertions are divided and the separation of the periosteum continued as far as possible without tearing it. The thigh is then adducted and the head of the femur raised out of the acetabulum. The periosteum can then be separated around the inner aspect of the bone. The femur is sawed through just above the lesser trochanter.

The right angular curved incision (Fig. 556, *D*) for exposure of the hip-joint begins at the same point above as the bow incision but makes a wider curve and passes down behind the great trochanter.

Excision of the Hip by an Anterior Incision.—The patient lies supine, the surgeon standing by the right side of the patient. The incision begins 1.25 cm. (½ inch) below the anterior superior spine of the ilium and passes downward and slightly inward for 11 cm. (4 inches). The opening through the muscles is made between the tensor vaginæ femoris and the glutei on the outer side, and the sartorius and rectus on the inner side. The joint is exposed and the neck of the femur sawn through in the direction of the external incision.

Excision of the Knee-joint.—As the knee-joint depends upon its ligaments for rigidity, a complete resection should be followed by bony ankylosis in order to give the best result. If it becomes necessary to remove the upper end of the tibia, and it is desired to secure bony ankylosis, a slice of the articular surface of the femur should be removed, even though it is not diseased, for the purpose of securing the flat bony apposition essential for good bony union. In children it is imperative that the epiphyseal line (especially the one at the lower end of the femur, as the greatest growth of the entire skeleton takes place here) be not disturbed, unless the extent of the disease makes it absolutely necessary. The epiphyseal line of the femur is horizontal with the tubercle of the adductor magnus. If the whole articular surface is

taken away by a horizontal cut, the whole epiphysis will have been removed. The epiphyseal line of the tibia is horizontal with the bottom of the tuberosities behind. The facet for the fibula is on the epiphysis. The line slopes downward and forward, so that the tubercle of the tibia is on the epiphysis. The line lies below the joint capsule. In 72 per cent. of cases subjected to excision between the ages of three and fourteen years, deviation of the knee takes place as a result of unequal growth of the lower end of the femur. After fourteen no deviation seems to occur. This is apparently due to the fact that the quadriceps muscle becomes weakened to a much greater degree than the flexors of the knee, the latter continuing to functionate because of their attachment to the pelvis. Tenotomy of the hamstrings in children under eight years of age should be done after excision of the knee-joint.

FIG. 557.—U-INCISION FOR EXCISION OF KNEE-JOINT.

This incision is useful for exposure of the patella or the knee-joint.

Arthroplasty for placing a flap of soft tissue between the bones should be done in the cases in which a movable joint is desirable and possible. This may be done at the time of the excision or as a later operation (see Arthroplasty, page 766).

Operation (Fig. 557).—General anesthesia or local venous anesthesia may be employed. The leg is emptied of blood and a tourniquet is applied 15 cm. (6 inches) above the knee. The knee is slightly flexed. The incision begins on the side of the limb opposite the posterior and upper part of the condyle, curves downward and across the front of the joint, midway between the patella and the tuberosity of the tibia, and ends at a corresponding point on the opposite side. This incision divides the skin and fascia down to the ligaments. The knee is now more strongly flexed, and the patellar ligament is divided and the joint opened. The joint is now strongly flexed, the patella turned up, and the lateral and crucial ligaments divided. The posterior ligaments are not disturbed.

The articular end of the femur is cleared of soft tissue, grasped with the lion-jaw forceps, and sawed through, care being taken to protect the popliteal vessels from injury. The same thickness of each condyle should be removed, to obviate the tendency to knock-knee or bow-leg. The bone should be divided in a line parallel to the plane of articulation. The foot should rest squarely upon the table, the leg be held in a perpendicular position, and in this position a thin slice of the upper end of the tibia sawed off in a line parallel with the articular surface. This is best done with the flat saw. As little bone as possible should be removed. Any diseased foci not removed by these cuts should be removed with the gouge or the curette. Oblique lines of division may be employed if thereby a larger amount of healthy bone can be preserved. This is always possible when the disease occupies but one side of the bone or opposite sides of the two opposing bones. Often in such cases an osteoplastic operation in the form of a step may be done to advantage, thus saving in the length of the limb. The two bony

surfaces, when apposed, should bring the leg into its natural line. A very slight degree of flexion is advantageous.

The patella, if not diseased, should be left. If it is diseased, the gouge or the curette may be used to scrape away the affected portions. If only the articular surface is affected, the bone may be steadied with the lion-jaw forceps, and the articular surface sawn off, leaving the anterior part of the bone. The diseased synovial membrane should be removed, and sinuses and pockets cleaned out with scissors and curet. The reflection beneath the quadriceps extensors should not be neglected. Any diseased spots in the remaining bone should be curetted.

The bones should be held together by a few strong sutures of chromicized gut passed through the lateral ligaments, which should be trimmed to give the best line for suturing, or metal or bone nails may rarely be employed (Fig. 558). Metal nails may be left projecting through the skin, and be removed in two or three weeks. The divided patellar ligament should be sutured. The necessity for drainage will depend upon the conditions present. The leg is dressed, and put up in a plaster-of-Paris case extending from the pelvis to the toes. It must be kept in an immobilizing splint, and maintained immobilized until solid bony union has been secured. The use of the Esmarch bandage in this operation permits the operation to be done more rapidly and, as no vessels of consequence are divided, the wound may be closed and the pressure of the dressings depended upon to prevent hemorrhage. A small drainage-tube on either side of the knee for twenty-four or forty-eight hours is desirable. There is usually much pain for about two days after the operation. This may be ameliorated and bloody oozing diminished by elevating the foot. The dressings should be changed in two days. Dressings should be put on so that the leg may rest undisturbed on a posterior splint while the dressings are changed. From four to twelve months elapse before the patient can walk on the leg. Before this he must go about with crutches.

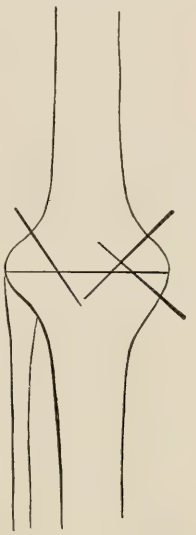


FIG. 558.—BONES HELD BY NAILS AFTER RESECTION OF KNEE-JOINT.

Many modifications of this operation are in use. Some employ a lateral incision along the outer side of the patella. Some carry the transverse incision above the patella, convexity upward. Another incision passes directly across the front of the patella, which is sawed through transversely. Kocher carried a curved incision from above the outer condyle downward and inward to the inner aspect of the tibia below the tuberosity, and chiseled off the tubercle bearing the patellar ligament.

Excision of the knee-joint without opening the joint is possible. This operation consists in removing the unopened capsule along with the two bone ends, and is performed through the large U-shaped incision, the synovial sac being dissected down from beneath the quadriceps muscle, and the bone ends sawed off beyond the attachments of the synovial membrane, so that they come away with the unopened joint capsule.

Resection of the knee cures tuberculosis because it gives immobilization, causes local hyperemia, and removes all or most all of the disease. The first two of these requirements may be met by less mutilating methods; and when they are met the last takes care of itself in a large proportion of cases. Resection is being done less and less.

It is possible, in cases in which resection seems indicated, simply to remove enough cartilage to cause ankylosis, implant the patella between the two bones, scrape out softened foci, and get the same proportion of cures as with resection. If bony union can be secured the disease stops. Tuberculosis of joints ceases when a joint no longer exists. Resection should not be done in children, and but rarely in adults.

Arthrectomy or Erasion of the Knee-joint.—The joint is opened by the U-incision employed for resection, or the patella may be sawed through. The flap is turned up and the diseased tissue in the bursa back of the quadriceps is removed in one mass. The capsule and synovial membrane attached to the tibia are removed in the same manner. The dissecting out of the synovial membrane should be continued until all diseased tissue down to bone and muscle is removed. The crucial ligaments may be divided, if necessary, to reach the back of the joint. The posterior ligament should be preserved. After dissecting out all disease of the soft parts diseased foci in the bone should be sought for and treated with the gouge or the sharp curette. The ligaments should be sutured back in place. A small tube for drainage on either side should be arranged so that it can be withdrawn at the end of forty-eight hours. The knee should be put up in an immobilizing splint with the slightest degree of flexion. While the ischemic constriction is generally advised against, I believe that here, as in excision, it enables the surgeon to work more rapidly, and more easily to discover diseased tissue; and it is, therefore, to be recommended.

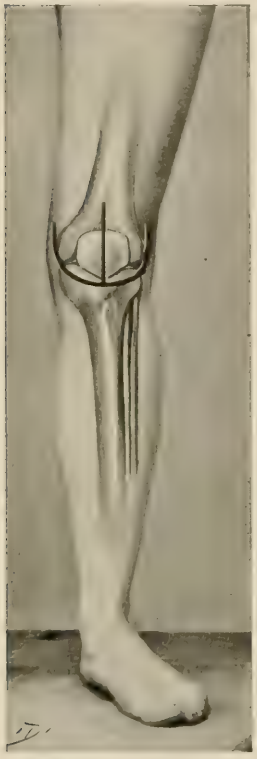


FIG. 559.—OPERATION FOR REMOVAL OF SYNOVIAL MEMBRANE OF KNEE-JOINT.

To the U-incision is added an incision which splits the patella, and freely exposes the synovial pouch behind the quadriceps muscle.

A curved incision, passing above the patella with the convexity upward is often useful. The patella is sawed through transversely, and the upper portion of the synovial sac is exposed by two lateral incisions. An operation which I can recommend consists in the ordinary curved incision, convexity downward, dividing the patellar ligament, and to this I add a median incision, bisecting this flap and the patella and freely laying open the pouch beneath the extensor muscle (Fig. 559). This gives free access, obviates transverse division of the patella, adds no hemorrhage, and simply splits the fibers of the muscle. No attempt to secure mobility immediately after arthrectomy of the knee for tuberculosis should be made; the best result is with ankylosis.

For opening the knee-joint for the purpose of securing the best possible access to all of its structures, the *U-shaped incision* has many advantages; and some disadvantages. If the operation is done for infection, or if, for any other reason, the flap cannot be sewed back in place, the ligaments become adherent and are replaced with difficulty.

For operating in uninfected cases a better result is secured by carrying the incision below the tubercle of the tibia. The tubercle with its ligamentous attachment is sawed free from the tibia, and the flap turned up with the

tubercle. At the conclusion of the operation the bone is attached back in place.

Incisions may be made longitudinally on either side of the patella. A route of access which I have used with satisfaction is in the middle line of the leg, *bisecting the patella.* The incision should begin in the midline of the thigh 6 or 7 cm. (2½ inches) above the patella, and pass downward across the middle of the patella and the patellar ligament to the tubercle of the tibia. The joint is opened above the patella. The bone is sawed through evenly so that it falls apart in two lateral halves. The quadriceps muscle and the patellar ligament are split, the wound retracted and the joint exposed (Figs. 560 and 561). Through this opening operations may be done on the synovial sac, on the cartilages, on the crucial ligaments and on intra-articular fractures of the tibia and femur. At the conclusion of the operation the

FIG. 560.—PATELLAR-SPLITTING INCISION FOR EXPOSURE OF KNEE-JOINT.

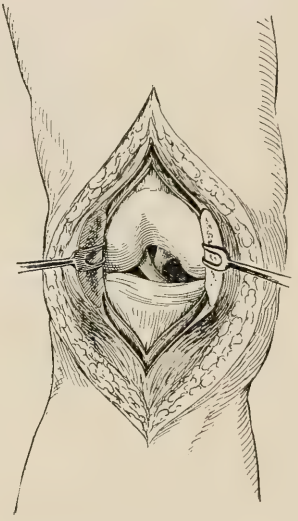


FIG. 561.—PATELLA DIVIDED VERTICALLY, RETRACTED AND KNEE-JOINT EXPOSED.

synovial sac should be closed by continuous sutures, one above and the other below the patella; the quadriceps, prepatellar and infrapatellar ligaments should be united with a continuous suture; and the skin wound closed with a running suture (Figs. 562 and 563), after the method of P. Babitzki.

The *oblique internal incision* is adapted to some cases, especially those with small muscles. It begins above at the inner side of the thigh, and passes downward and forward to the upper inner side of the patellar tubercle of the tibia. Such an incision should be about 13 cm. (5 inches) long. The capsule of the joint is opened above the inner condyle without dividing the ligaments, and separated from the front of the femur as far as the middle front of the bone. The patella is then pressed outward and dislocated to the outer side of the knee and the knee flexed. This gives exposure of the articular surfaces and crucial ligaments. When the leg is extended the patella slips back into normal position.

Excision of the Ankle-joint.—This operation was formerly done for tuberculosis and injury. It is no longer resorted to as a typical operation in the latter condition; and in tuberculosis it has given results which have

proved so unsatisfactory that it is now but little used. Quite invariably tuberculosis of the ankle-joint is associated with disease of the tarsal bones, and excision of the joint has required subsequent operations to effect a cure. Amputation, on the whole, gives the best assurance of a cure, and, with a good prosthetic apparatus, as useful a limb. It may be resorted to in advanced cases. More recently the tendency is to more conservative methods; and, the modern treatment of tuberculosis being applied, the old mutilating operations are less commonly called for.

Excision by an External Curved Incision (Fig. 564, *L*).—An incision begins just posterior to the fibula 5 cm. (2 inches) above the malleolus, passes down the posterior border of the bone, curves forward beneath the malleolus, and terminates on the outer aspect of the dorsum of the foot at the astragaloscaphoid

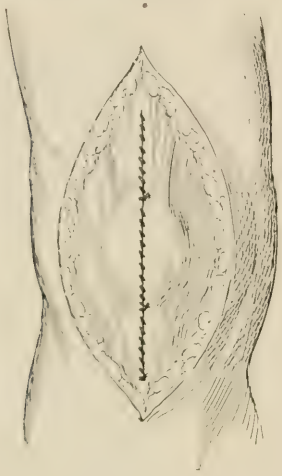


FIG. 562.—CLOSURE OF WOUND AFTER PATELLAR-SPLITTING OPERATION FOR EXPOSURE OF KNEE-JOINT.

The synovial sac is closed with continuous sutures above and below the patella.

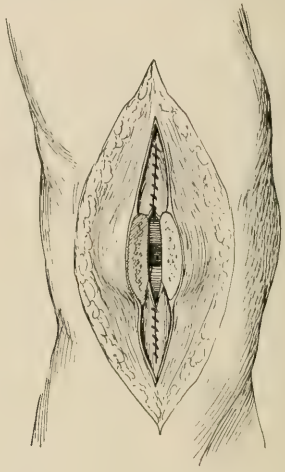


FIG. 563.—PREPATELLAR FASCIA SUTURED, UNITING THE TWO HALVES OF THE PATELLA.

The skin wound should be closed over all. Instead of a median skin incision in this operation the skin incision may be curved laterally, thus turning aside a crescentic flap. This places the skin wound at one side and separates it from that of the patella.

articulation. The fibula is exposed and the periosteum divided and reflected, carrying with it the two peronei tendons. The fibular attachment of the external lateral ligament is divided, and the lower inch of the fibula cut off. By retracting the skin-flap and tendons the anterior surface of the lower end of the tibia is brought into view. The foot is now completely inverted, exposing freely the articular surfaces of the joint. The necessary resections can now be made, the foot replaced, and the parts sutured.

Excision of the Ankle by Bilateral Incisions (Figs. 545, *B*; 546, *B*).—A vertical incision 8 cm. (3 inches) long is made along the anterior part of the fibula, ending just below the tip of the malleolus. It is joined at its lower extremity by an incision which curves around beneath the malleolus and ascends for 2.5 cm. (1 inch) behind the fibula. Through this incision the periosteum and the tendons are elevated from the fibula, the lateral ligaments divided and the lower inch of the bone cut off. The outer aspect of the

tibia in front and behind is reached through this wound and denuded of periosteum. An inner longitudinal incision is carried for 8 cm. (3 inches) along the inner surface of the tibia, ending at the tip of the malleolus. This is joined at its lower end by a short incision at right angles. The periosteum of the tibia is incised longitudinally and elevated anteriorly and posteriorly until the denudation meets that which was started from the outer side. The internal lateral ligament is divided, care being taken to protect the structures passing beneath the malleolus. The lower end of the tibia is then divided with the small saw and removed. The articular surface of the astragalus is sawed off through the outer wound, or, if necessary, the whole bone may be removed.

Excision of the Ankle by the Transverse External Incision.—The incision is begun anteriorly, 1.25 cm. (½ inch) below the center of the ankle-joint, passes outward and backward below the malleolus, and thence curves up-

FIG. 564.—EXTERNAL INCISIONS FOR EXCISIONS OF AND ABOUT THE ANKLE-JOINT. *A*, Excision of calcaneum (*Ollier*); *B*, excision of astragalus (*Ollier*); *L*, Excision of ankle-joint (*Lauenstein*).

ward to the tendo Achillis. The common extensor tendon is avoided, also the musculocutaneous and short saphenous nerves. The foot is strongly inverted, the external ligaments divided, the tendons retracted, and the operation completed as above.

Excision of the First Metatarsophalangeal Joint.—This operation is best done through an incision on the dorsum of the foot, placed just internal to the tendon of the great toe. The scar of this wound comes between the first and second metatarsal bones, and is least exposed to irritation.

ARTHROTOMY

Arthrotomy, or incision into a joint, is done for purposes of drainage of septic joints, for the liberation of fluids and blood, for the removal of loose cartilages and floating bodies, for the removal of foreign bodies, and for the purpose of introducing medication into a joint. For purposes of drainage the opening, when possible, should be made at the lowest part of the joint. In operating for the purpose of securing drainage the general principles of

surgery, demanding opening at the most dependent part, must often be modified by the anatomic peculiarities of the joint.

The knee-joint, particularly, has suffered from this, it being customary to open it for drainage laterally, leaving the posterior half of the joint sac undrained. It is not difficult to reach the joint through an opening made at its most posterior part.

A **posterior incision** offers drainage at the bottom of the joint-sac as the patient lies recumbent; and in virulent infections is much to be preferred to the lateral opening. Posterior drainage may be secured through incision directly over the posterior aspect of the condyles. This opens into the pouches of synovial membrane lying in front of the heads of the gastrocnemius. Care should be taken not to injure the long saphenous vein or the external peroneal nerve.

A **vertical postero-external incision** is made along the anterior border of the tendon of the biceps. The knee is then flexed and the tendon retracted backward. The iliotibial band of fascia is cut and retracted. This brings into view the joint capsule which may be opened at either above or below the tendon of the popliteus. If the opening is made below the popliteus, the lowest point in the joint cavity is opened.

A **postero-internal incision** is made along the anterior border of the tendon of the sartorius, the joint is then flexed, the tendon moves backward, and the joint is opened posterior to the lateral ligament.

The two latter straight incisions serve best for securing drainage of the posterior part of the joint. Continuous irrigation may be carried out through these openings in the recumbent patient with the greatest satisfaction.

An **internal curved incision** begins at the inner border of the patella 2 cm. (¾ inch) below its upper border, passes downward nearly to the tibia, and thence curves backward to the internal lateral ligament. This exposes the front of the internal condyle, the anterior half of the internal semilunar cartilage, and the anterior crucial ligament.

An **external curved incision** begins at the upper part of the outer border of the patella, passes downward nearly to the tibia, and thence curves backward to the external lateral ligament. This exposes the front of the external condyle, the external semilunar cartilage, the posterior surface of the patella and the synovial structures at the outer side of the patella.

A **vertical antero-external incision** passes along the outer border of the patella from the external semilunar cartilage to a point 2 or 3 cm. (1 inch) above the level of the upper border of the patella. This incision opens the synovial sac behind the quadriceps muscle, and exposes the synovial structures at the outer side of the patella.

The Prevention of Ankylosis

The Prevention of Ankylosis by Injections of Oil.—Adhesions between the synovial surfaces in joints follow inflammatory processes. These adhesions may often be prevented by the injection into the joint of sterilized olive oil. This operation is especially indicated after the breaking up of fibrous adhesions in order to prevent their re-formation. Baer found that joints tolerate as much oil as they will hold, and that when filled passive motion is less painful. The oil is injected with strict asepsis by means of a syringe provided with an easily separable needle. The oil should be at body-temperature and the needle should inflict the least possible trauma. This treatment is employed for the cure of various adhesive arthritides.

Sterilized yellow vaselin is useful for this purpose. The hip-joint holds 20 to 25 c.c. without difficulty. The knee holds 10 to 12, at the most 15 c.c.

(4 drams). The shoulder holds 15 c.c. Embolism may result if a vessel is punctured. For this reason the surgeon should be sure that the lubricant enters the joint. It is best to use a tube 10 cm. long, one end of which is provided with a brass ring which can be screwed on the ordinary collapsible vaselin tube and the other end screwed into a canula. The whole apparatus, with the vaselin tube, is sterilized by boiling. The skin is sterilized with iodin. The joint is punctured, the trocar removed, the vaselin tube connected, and the contents of the tube squeezed into the joint. The injection is not made until synovial fluid escapes from the canula. If the synovia is turbid and has the appearance of infection, the injection is not made.

The shoulder-joint is best punctured below the hindermost corner of the acromion; the knee, by puncture outward at the upper inner angle of the patella. In the hip, it is best to expose the capsule by an incision above the trochanter. One also exposes the jaw-joint by incision.

For further discussion of the prevention of ankylosis see Fractures Involving Joints, page 518, and Arthritis and Synovitis, page 657.

Operations for Ankylosis

Arthroplasty for the formation of a movable joint in the presence of ankylosis is one of the triumphs of modern surgery. The operation consists in separating the bones in the joint by means of a saw or chisel and turning in between them a layer of soft tissue. For this purpose fascia, muscle, periosteum, cartilage, bursal sac, tunica vaginalis from hydrocele, and fatty tissue have been used for the formation of a joint. In performing this operation the bones should be chiseled apart as nearly as possible in the line of the joint, and the surfaces evenly smoothed off. Unnatural bony prominences and scar tissue should be removed. All parts of the synovial membrane which is covered by adhesions and has lost its synovial character should be covered with the transplanted tissue. Structures which may limit motion are dealt with as is required. Muscles, tendons and fascia may require to be lengthened or divided. One of the most satisfactory methods consists in cutting out a pedunculated flap of fascia and fat near the joint, and swinging it between the bones to cover the rough bone surfaces. This flap is sutured in place to the capsule. Some fatty tissue is desirable in this flap. Muscle and fat may be used if fascia is not available. The overlying wound is then closed and the joint immobilized. At the end of ten or twenty days, passive motion should be begun. This should be practised every day, or every other day at least. If there is great pain motion should not be attempted. Moderate pain may be endured. A continuance of the passive motion is essential to success. If motion is discontinued, the interposed tissue becomes converted into scar. Continuation of motion results in the formation of a joint.

An arthroplasty with interposition of adjacent flap or transplanted fascia, if aseptically done, may be expected to give a good result. A practically normal sliding joint with all of the normal possibilities of motion is produced. A new synovial membrane is formed, with loculi lined with cells similar to those found in synovial surfaces. A fluid similar to synovial fluid is secreted. The condition is like that in which bursal sacs develop over bony prominences. The end of the bone becomes attached to the new tissue by a dense fibrous layer like cartilage.

The interposition of soft tissue flaps to cure ankylosis is the ideal operation in cases of hopeless destruction of joints. In these cases operations on any of the important joints may be done. A case of total ankylosis of both hip-joints has been restored to flexibility so that the patient could

flex the thighs to a right angle. Ankylosis is bony, cartilaginous, fibrous, periarticular (ligamentous and capsular), and extra-articular (contractures of soft parts such as tendons, muscles, fascia, etc.). Bony, cartilaginous, ligamentous, and usually capsular ankylosis are best treated by arthroplasty. The extra-articular varieties yield to stretching, incision and excision of soft parts.

Operations for ankylosis due to adhesions and contractures of soft tissues need not necessarily involve the bone. Nonosseous ankylosis, which is not amenable to treatment by passive motion or oil injections, demands operation. Division or plastic elongation of tendons and muscles is often indicated.

In ankylosis with fixation of the capsule to the head and neck of the bone, with contracture of the capsule, the capsule with the involved ligaments

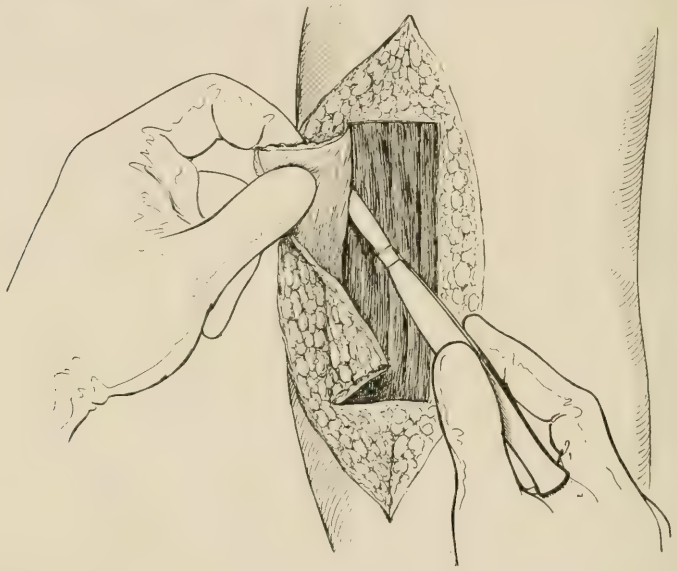


FIG. 565.—CUTTING FASCIA LATA WITH SUPERFICIAL FATTY FASCIA FROM OUTER OF THIGH FOR TRANSPLANTATION.

may be excised, and the head and neck of the bone covered with aponeurosis or muscle turned in from the neighborhood. Division of the capsule without its excision does not suffice. Motion—free from tension—must be secured, even to the point of flail motion. In the knee, when the ankylosis is due to involvement of the capsule and ligaments in inflammatory tissue, and these structures are contracted and inelastic, all of the periarticular ligaments and the capsule, excepting the hamstring tendons, the quadriceps, the patellar ligaments, and the crucial ligaments, should be dissected away.

Transplanted soft tissues are the most satisfactory substances for these purposes, especially fascia and fatty tissue. They should preferably be taken from the patient's own body, but not necessarily from the region of the joint (see Grafting of Soft Tissues, Vol. III).

Instead of using fascia, the addition of muscular tissue or a layer of adipose tissue has decided advantages. Good results are secured with interposed muscle in elbow resections. Deltoid muscle has been used in the treatment of *ankylosis of the shoulder-joint*, and pronator radii teres and supinator longus in the *elbow*. Tunica vaginalis from hydrocele is useful.

The employment of omentum for the same purpose should be borne in mind. The anterior ligament of the elbow also lends itself for interposition. Whatever soft tissue is used, a sufficient thickness must be interposed to permit the formation of a joint sac within its structures, and this cannot take place if the tissue is thin and if it unites the two bones too intimately (Fig. 565). For the *wrist* a flap of joint capsule may be used.

The *interposition of periosteum for ankylosis* has been practised with much success. The bones should be separated by a chisel as near as possible to the natural line and the ends given their natural shape. Exostosis should be removed, and unhampered movement secured. A flap of periosteum of the desired size is chiseled from the tibia, care being taken to include the osteoblastic layer. Such a flap is placed over each bone-end and sutured

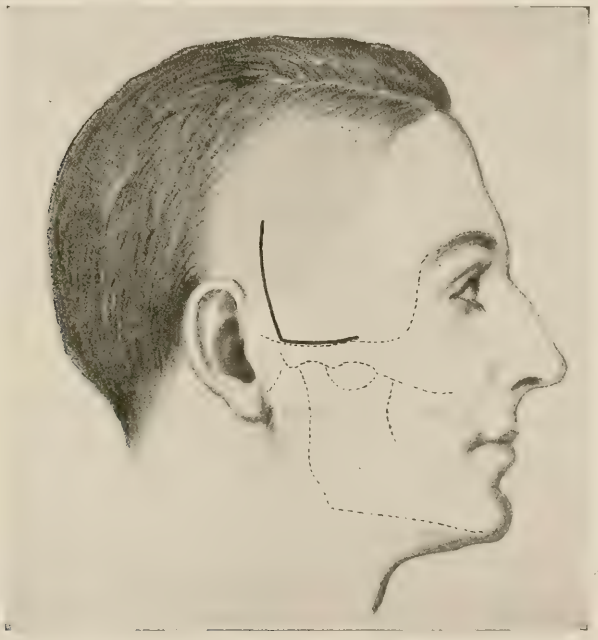


FIG. 566.—INCISION FOR PLASTIC OPERATION ON TEMPORO-MAXILLARY JOINT.

fast. This tissue, above all others, seems best adapted to this purpose, as it is the natural barrier against osteophytic growth. With periosteum to periosteum the joint should be immobilized for three weeks or longer. Passive motion should then carefully be instituted. The results in elbow cases under this treatment have been remarkably good.

Cartilage grafts in joint resections are used with excellent results. After resection of the elbow, tibiotarsal cartilage and cartilage from the scaphoid and astragalus may be applied to the freshened bone-ends. The grafts are really osteocartilaginous, and are best taken from freshly amputated parts.

The *interposition of foreign membranes in ankylosis* is aimed to accomplish the same results as are secured by the use of living tissue. For this purpose sterilized bladder has been used. Chromicized pig's bladder has been used. Some good results have been secured, but not so good as have been obtained by interposing living tissue.

Arthroplasty for ankylosis of the temporomaxillary joint has been worked out most effectively. The principle first applied by Helferich (Verhandl. d. deut. Gesell. f. Chir., 1894, xxiii), who interposed part of the temporal muscle, is used. In unilateral ankylosis, the full side of the face, and not the flattened side, is the place of ankylosis and the side to be operated upon. The incision best adapted to this operation is L-shaped. The vertical arm lies in front of the ear, is in a line with the posterior border of the ramus of the lower jaw, and extends from the upper border of the zygoma 4 cm. (1½ inches) upward. This is joined by a horizontal incision 2 cm. (¾ inch) long which lies along the upper border of the zygoma (Fig. 566). It should be remembered that the joint cavity lies under the brain from which it is separated only by a thin plate of bone.

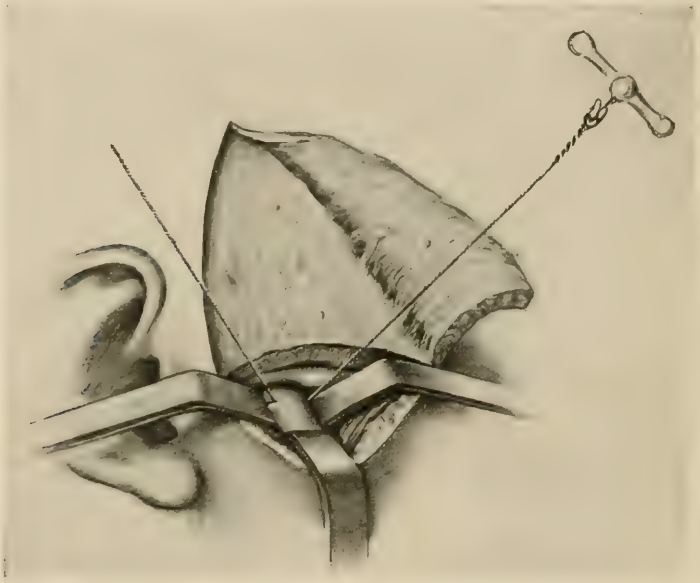


FIG. 567.—NECK OF LOWER JAW DIVIDED BY WIRE SAW.

The scalp is dissected free over the triangle marked out, and also below the zygoma. The wound is then deepened below the zygoma and the neck of the jaw exposed. The neck is freely isolated. Two curved retractors are useful for this purpose with the special object of protecting the internal maxillary artery which lies against the inner side of the neck. If it is opened, it should be ligated at the bifurcation of the external carotid. A wire-saw is passed around the neck and it is divided (Fig. 567). The head is not removed. If bony ankylosis holds the head, about 1 cm. (⅓ inch) should be resected from the neck. The lower jaw can be freely moved as soon as the bone is divided. A flap of fat and temporal fascia, having the shape of an inverted U is turned down outside of the zygoma (Fig. 568) and its free end tucked in the bony gap below the head, and fixed by sutures on either side to the connective tissue and periosteum (Fig. 569). The wound is closed without drainage. A block of wood is inserted between the back teeth on the diseased side, and the jaw kept immobilized for two weeks while the flap heals in place. It prevents pressure necrosis of the flap. Mastication should be begun not sooner than two weeks after the operation.

An operation which gives a more open access to the joint is that by which a segment of the zygoma is cut out and temporarily turned down in an osteoplastic flap (page 740).

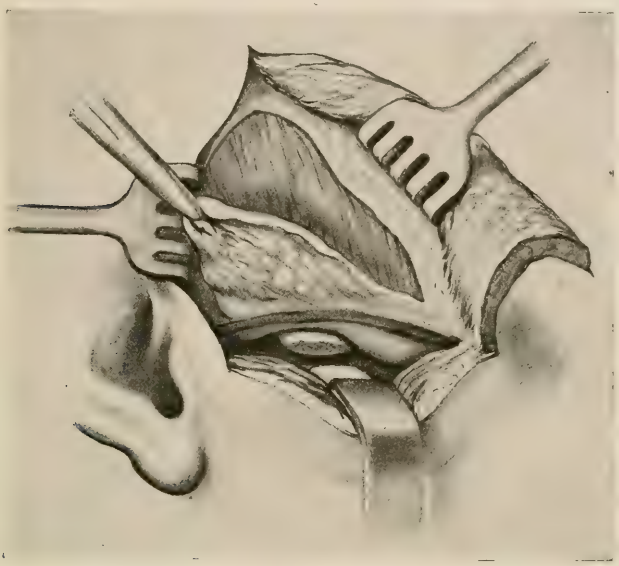


FIG. 568.—FLAP OF TEMPORAL FASCIA AND FAT FREED FOR INSERTION IN BONY GAP.

FIG. 569.—FLAP SECURED IN POSITION IN THE BONY INTERVAL BELOW THE HEAD OF THE LOWER JAW.

Arthroplasty for Ankylosis of the Shoulder.—An anterior incision along the anterior margin of the deltoid muscle is made about 12 cm. (5 inches) long. The head of the humerus is exposed, and separated from the scapula with a curved chisel and knife. The glenoid cavity is smoothed and deepened, and rough bone removed from the head of the humerus. A second incision

is carried inward on the chest at a right angle from the upper end of the first incision. The skin is elevated over this triangle, and a flap of fat, fascia, and pectoralis major muscle, 9 cm. (3½ inches) wide and 11 cm. (4½ inches) long is made. The pedicle of this flap is outward and is left attached to the humerus. It is swung outward and placed over the head of the humerus, completely covering the glenoid cavity, and made fast with a few catgut sutures. In some cases it may be necessary to remove the head of the humerus at the anatomic neck. Instead of using a pectoral flap a flap of

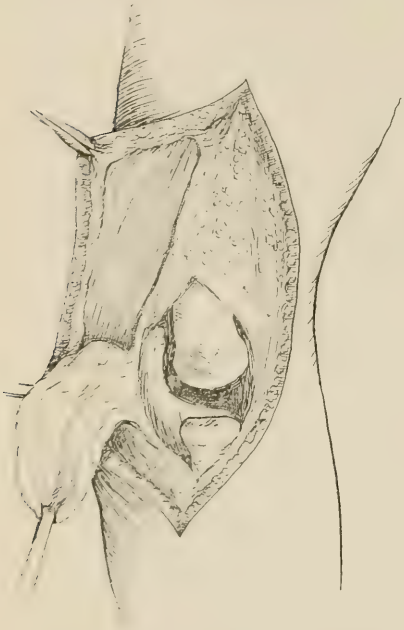


FIG. 570.—ARTHROPLASTY OF ELBOW.

Showing bones separated, and flap of fatty fascia detached and ready to place between the bones. There is an incision on either side of the joint, and flaps are turned in on either side.

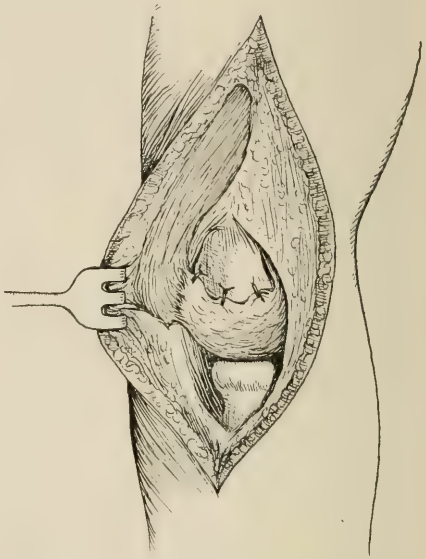


FIG. 571.—ARTHROPLASTY OF ELBOW

Flap has been placed between the bones and sutured.

deltoid may be taken and left attached above; or a piece of fascia from the outer side of the leg may be used. In the latter case the transverse incision to the chest is not made. The interposed fascia may be doubled.

Arthroplasty for ankylosis of the elbow is done by the principle of the interposition of soft tissue. When due to fracture, the bones should be restored to position. When the parts have their normal contour, and an ankylosis, due to insoluble adhesions exists, the principles, as worked out by Helferich, Quénu and Murphy are applicable. The arm should be rendered ischemic by the rubber bandage. The joint was formerly exposed by a long posterior incision, extending from the middle of the upper arm to a point below the olecranon. A better operation is by making two incisions, one on either side of the joint about 1.3 cm. (½ inch) from the olecranon. The ulnar nerve should always be found, dissected free, and protected during the operation. The incisions are 15 cm. (6 inches) long and extend through the skin and superficial fascia. Usually the olecranon can be chiseled free from the

humerus. The head of the radius sometimes is adherent and needs to be detached from the humerus. The olecranon need be divided and turned up only in exceptional cases. Rarely the lower end of the humerus must be sawed off. The bone-ends are smoothed off, and the joint made perfectly free and movable. A flap of fascia and fat is taken from the inner side of the arm and one from the outer side. The bases of the flaps are upward. These two flaps are turned in over the end of the humerus and arm bones and sutured. Each should be long enough to be drawn through the joint and broad enough to cover all of the bone exposed (Figs. 570 and 571).

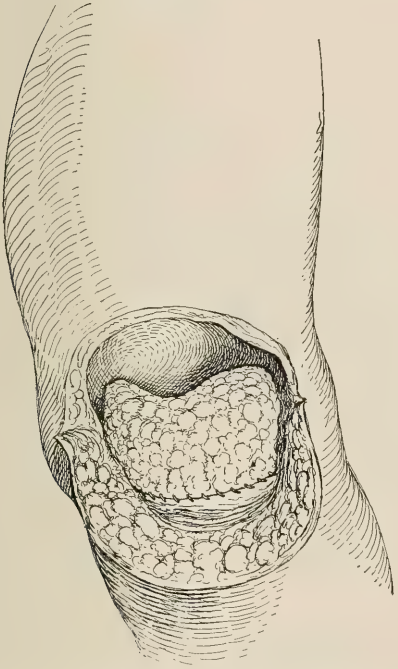


FIG. 572.—GRAFT OF FASCIA SUTURED OVER LOWER END OF HUMERUS.

The fatty surface is outward and so placed as to articulate with the radius and ulna.

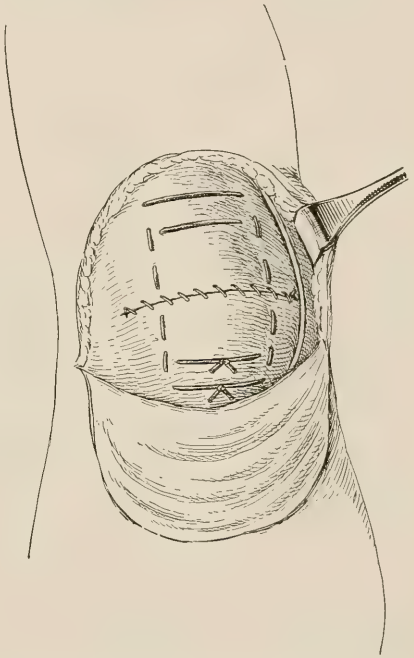


FIG. 573.—OLECRANON UNITED BY STRONG SUTURES AND JOINT CLOSED.

The ulnar nerve is seen at the side, dissected free and uninjured.

Operation by a curved posterior incision gives the best exposure for division of the olecranon. The back of the joint is exposed by an inverted U-shaped incision. The ulnar nerve is dissected free and protected by gauze. The olecranon is divided transversely opposite the joint. If the olecranon is adherent to the humerus, the lower end of the humerus is removed with the upper part of the olecranon. If the tip of the olecranon can be saved, it should be left attached. Whatever is necessary to separate the bones is done. The lower end of the humerus is rounded, and free mobility secured. A flap of fascia with the overlying fatty tissue may be dissected from the back of the arm, or it may be taken from the outer side of the thigh. The piece of fascia to be used should be 10 by 13 cm. (4 by 5 inches) in size. It should be dissected free and removed. This piece of fascia is removed with a layer of overlying fat attached to it. The fascia is placed over the lower end of the humerus, fat side down. It is sutured to the anterior

part of the capsule and then to the posterior part with a continuous catgut suture (Fig. 572), so that it forms a smooth covering over the end of the bone. The capsule and ligaments are sutured with chromic catgut. The olecranon is sutured with kangaroo tendon or double chromic catgut (Fig. 573), and the wound closed.

The arm in these cases should be put up on a splint at an angle of 135 degrees.

In bony ankylosis of the elbow, a median posterior incision may be made and the skin and superficial fascia laterally dissected free. A pyriform flap, composed of the deep fascia lying on the triceps 11 cm. (4½ inches)

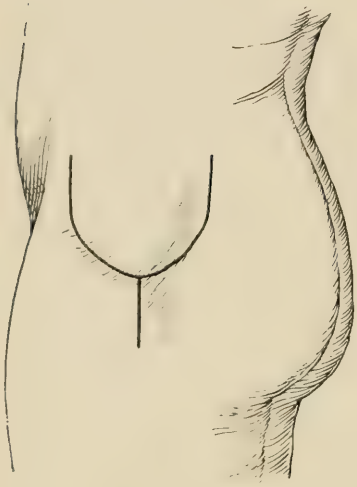


FIG. 574.—ARTHROPLASTY OF HIP.
Incision used by J. B. Murphy for exposure of joint.

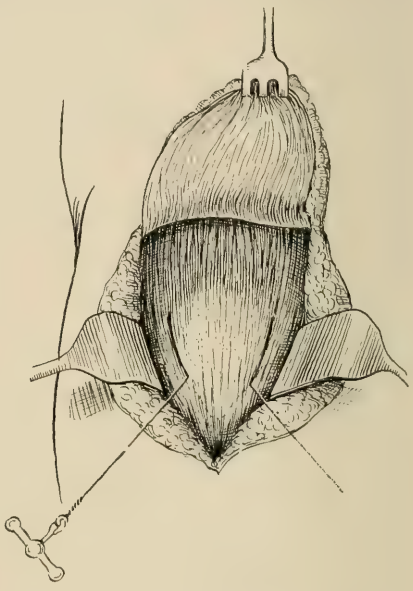


FIG. 575.—ARTHROPLASTY OF HIP.
Flap of skin, fat and fascia lata turned up and trochanter divided with wire saw.

long and 6 cm. (2½ inches) wide at its upper end, is cut out. It receives blood-supply through its base, which is just below the level of the top of the olecranon. The olecranon is then sawed through obliquely from before backward with a wire-saw. All of the abnormal bony connections are then divided with the chisel and exostoses removed. The flap of fascia is drawn into the joint around the inner side of the olecranon, sutured at its edges to the capsule, and the olecranon returned in place. Passive motion in these cases is begun on the tenth day.

Arthroplasty for ankylosis of the wrist is done for ankylosis between the radius above and the scaphoid and semilunar bones of the carpus below. A vertical incision is made over the back of the wrist extending 2.5 cm. (1 inch) above and below the joint. It passes only through the skin and superficial fascia. The extensor tendons are retracted, and a U-shaped flap with its base upward is cut from the deep fascia and the capsule of the joint. The bones are then separated by chisel, the flap placed between, and sutured to the anterior capsule. In some cases some bones will require to be removed. An anterior incision may be required to facilitate the operation. After suturing and dressing the wound, a splint is left on for

seven days, and then passive motion begun. The splint may be dispensed with at the end of fourteen days.

Arthroplasty for ankylosis of the hip may be successfully accomplished by the interposition of fascia and connective tissue. The resisting capsule and ligaments should be divided or removed, as described for the treatment of contractions and adhesions of the soft parts. Resisting muscles should be divided or stretched. In cases of bony ankylosis of the hip, a U-shaped incision is made, embracing the great trochanter, the base of the flap being above and measuring about 8 cm. (3 inches) across. The incision is begun 8 cm. above the trochanter, and extends downward 5 cm. (2 inches) below the trochanter, which lies in the centre of the U. The incision goes

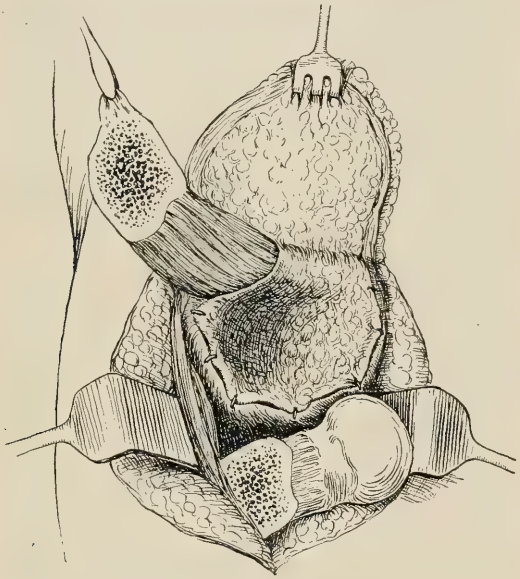


FIG. 576.—ARTHROPLASTY OF HIP.

The superficial flap has been raised, the trochanter and its attached muscles have been turned up, the joint has been opened, the head and acetabulum made ready, and a flap of fascia lata and fat dissected free from the superficial flap and sutured into the acetabulum. The next step consists in placing the head in the socket and sewing the trochanter back in place.

through the deep fascia and down to the muscle. Or the U may rest upon the great trochanter, and be supplemented by a vertical cut below, forming the "goblet incision" (Fig. 574). This flap of skin, connective tissue, and fascia lata is turned upward. The muscle bundle which is inserted into the great trochanter from above is then split on either side and the wire-saw passed beneath. The saw cuts off the great trochanter with its muscular attachments (Fig. 575). The obturator and pyriformis muscles constitute the bulk of this muscular flap, which also is turned upward, exposing the joint-capsule. The capsule of the joint is then opened and separated all the way round, and the head removed from the acetabulum by means of a curved chisel and fracturing force. Bony projections are smoothed off and the acetabulum deepened.

A flap of fascia lata in the U-shaped flap is then dissected free, fitted into the acetabulum to make a lining for it, and sutured to the capsule of the joint around the margin (Fig. 576). The free border of the flap which

projects beyond the acetabulum may be sutured to the periosteum and capsule attached to the neck of the femur. The trochanter is sutured back in position and the wound closed. Tension is relieved by traction-extension with about 20 pounds. The limb is put up in the abducted position. Careful passive motions are begun about the tenth day, and practised daily. The movements consist in lifting the leg from the bed. Abduction and adduction are begun at the end of two or three weeks. The traction should be continued for three or four weeks. Active motion is attempted from the third to the fifth week. Walking with crutches may be allowed about the fifth to the seventh week. Fairly free motion is ultimately secured.

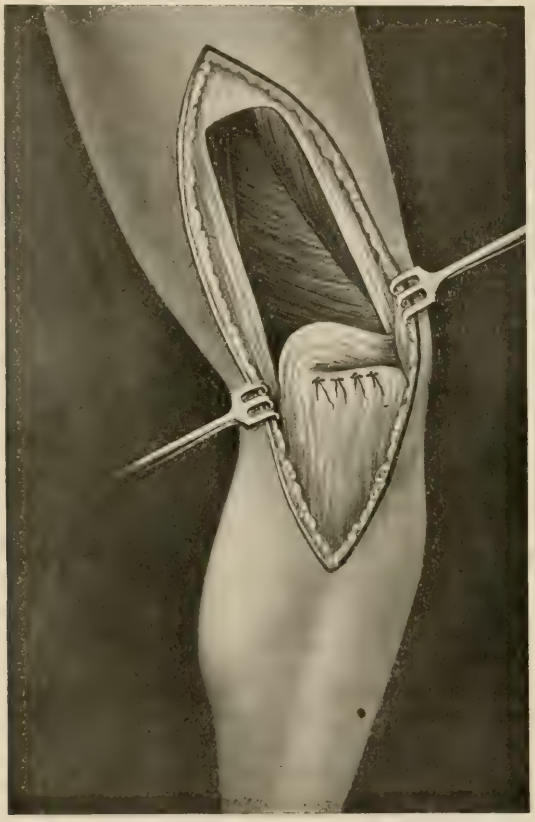


FIG. 577.—OPERATION FOR ANKYLOSIS OF KNEE.
A flap of fascia is carried between the bones to form the new joint.

Arthroplasty for knee-joint ankylosis gives most gratifying results. A vertical incision along the outer side of the joint is made after emptying the leg of blood and applying a rubber tourniquet. This extends 15 cm. (6 inches) above and 7.5 cm. (3 inches) below the joint. A second vertical incision about 10 cm. (4 inches) long is made on the inner side of the joint. Through these incisions the patella is freed from the femur. The adhesions between the femur and the tibia are then divided. If contracted and adherent capsule and ligaments are present, they are removed. A bony union is divided with the chisel. If necessary a part of the upper surface of the tibia is removed. An intercondyloid ridge should be preserved. A

flap of fascia lata, together with a layer of muscle, the base being below, is dissected from the outer surface of the vastus externus. Some surgeons take two rectangular flaps of capsule, ligament and subcutaneous fat, from either side of the joint. These flaps are about 6 cm. (2½ inches) square. The base of each is downward and attached to the upper end of the tibia. The flap is drawn through the joint between the two great bones and sutured to the capsule (Fig. 577). A smaller flap is cut from the fascia of the vastus and sutured in place between the patella and the femur. The lateral ligaments are sutured back in place, the wound closed, and splints applied. The joint is kept in a splint for three weeks, but passive motion and massage are applied after the first week. Forcible motion under anesthesia may be required at times.

For exposure of the joint, the U-incision, with division of the patellar ligament, may be used. Fascia may be taken both from the vastus internus and externus. If the lateral ligaments have not been divided but the operation done through the U-incision it is well to apply about 1 kilo (2 pounds) extension to the leg to take the pressure from the new flap between the bones.

This principle has been employed in operating for *bunion*. After resecting the head of the metatarsal bone a soft flap is sutured in the joint, and a movable joint secured.

Arthroplasty for ankylosis of the patella is often necessary following inflammation of the knee-joint or operation or injury of the patella, when the bone is found adherent to the femur, although there is no evidence of adhesion between the femur and tibia. To restore the function of the joint the patella must be freed from the femur and some tissue must be interposed between the two bones. For this purpose an incision may be made along the outer border of the patella and continued over the vastus externus. The bones are separated, a flap of fat and fascia lata is cut from the outer region of the joint and thigh, and inverted between the bones. Two or three sutures should fix it to the opposite side. These sutures should first be attached to the edge of the flap and the needles passed between the bones and through the skin.

Another method consists in dissecting free the patella in the U-shaped flap employed for resection of the joint. The flap is turned up and the reflection of synovial membrane, which lies above the patella and behind the quadriceps tendon, is freed and brought down behind the patella. The flap is then replaced.

The prepatellar bursa may be interposed. A vertical incision is made along the outer side of the patella. The soft parts are dissected away from the front of the patella and the adjacent joint region. The patella is then detached from its adherence to the femur. This separation should be carried up beneath the quadriceps extensor tendon. A dissection is then made between the prepatellar skin and the subcutaneous tissue. All of the tissues between the bone and the skin are dissected free from the skin. When this dissection has been carried a little beyond the inner edge of the patella, this mass of connective tissue, which contains the unopened prepatellar bursa, is divided above and below, and carried between the patella and femur. It is left connected internally. Its free edge is sutured to the tissues along the outer border of the patella. If the amount of tissue available is very scant, a flap of fascia may be drawn through, taken from over the vastus externus. The wound is closed. After healing, passive motion should be inaugurated.

Transplantation of Joints

The transplantation of soft tissues, bone and cartilage may all be undertaken separately or all three of these structures may be transplanted together in the form of a complete joint. The transplantation of fresh still warm,

human joints gives the best results. The material is supplied by amputations for traumatism, dry gangrene, tumors, and from the bodies of persons killed by sudden traumatism. Fresh human bones with their articular ends, making a graft as long as 30 cm., may be transplanted. Single bone-ends entering into a joint may be employed or a whole joint may be used. Lexer transplanted a complete knee-joint in a girl eighteen years of age. At the end of a year and a half she walked with but a slight limp and some rocking of the knee-joint. One of his cases was a man of thirty-eight years of age, in whom resection of the upper articular end of the tibia was done for sarcoma. The defect was at once filled by a similar piece from a tibia of a leg amputated for senile gangrene. In three months the patient had practically normal function. Amputated toes and fingers may be used to replace amputated members of the same kind.

The technic of these operations is most important. The strictest asepsis is essential. A slight infection spoils the result and may even jeopardize the life of the patient. The nutrition of the parts should be interfered with as little as possible. Tension should be guarded against. If suturing cannot be relied upon to hold the bones in place, pegs may be used. By shaping the bone-ends with offsets and depressions to receive them, pegs may be dispensed with. The warm bone should be transferred to its new bed as quickly as possible and without receiving any treatment excepting protection from infection. Excess of soft tissues should be removed, but the periosteum left. As the absorption of the broken-down marrow causes fever, it is best to clear it out. The cavity may be filled with bone-filling.

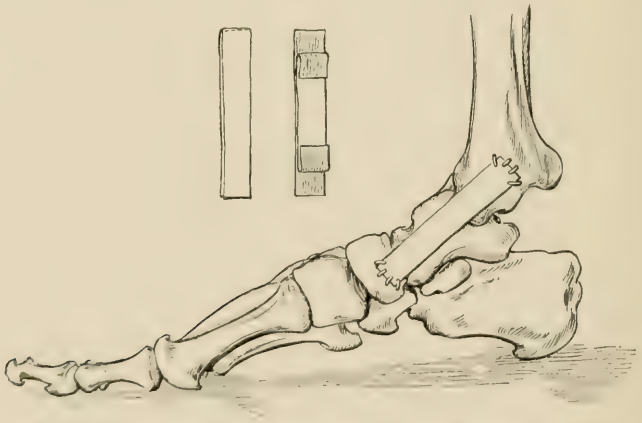


FIG 578.—PERIOSTEAL GRAFTING TO STRENGTHEN ANKLE.

The periosteal graft, taken from the inner surface of the tibia, is folded once upon itself with the osteogenetic surfaces apposed. The ends are folded back to expose a broad surface of the osteogenetic side to be placed against the bone for attachment.

OPERATIONS TO STRENGTHEN WEAK JOINTS

Joints which have become weak or loose from injury or disease, causing rupture or relaxation of ligaments, may be strengthened by restoring the relaxed ligament by suturing it, by folding an elongated ligament, or by the implantation of fascia, tendon or other strong tissue. Fascia from the front of the quadriceps muscle is turned down to strengthen a weak patella (page 733). A strip of periosteum serves admirably. A piece of periosteum, twice the width required may be cut from the internal surface of the tibia or from a rib, folded once upon itself, osteogenetic layer inside, and then

sewed to the bone on either side of the joint in the position at which it is desired that motion should be checked (Fig. 578). The osteogenetic layer should be turned back on either end so that it shall lie against the bone to which it is desired that it should become attached. This is the method of M. Katzenstein.

Operations to Compensate for the Loss of an Epiphysis

In a growing child the loss of an epiphyseal center in the leg or forearm means distortion, as the growth of the other bone continues. The loss of either epiphysis in the tibia or fibula may be supplied by taking half of the

Fig. 579.—Operation to Compensate for Loss of Epiphyseal Line of Upper End of Tibia.

The fibula with its upper epiphysis is split and moved under the remains of the tibial epiphysis.

Fig. 580.—Operation to Compensate for Destruction of Lower Epiphyseal Cartilage of Tibia.

The fibula is split, and swung across to unite with the remains of the lower tibial epiphysis.

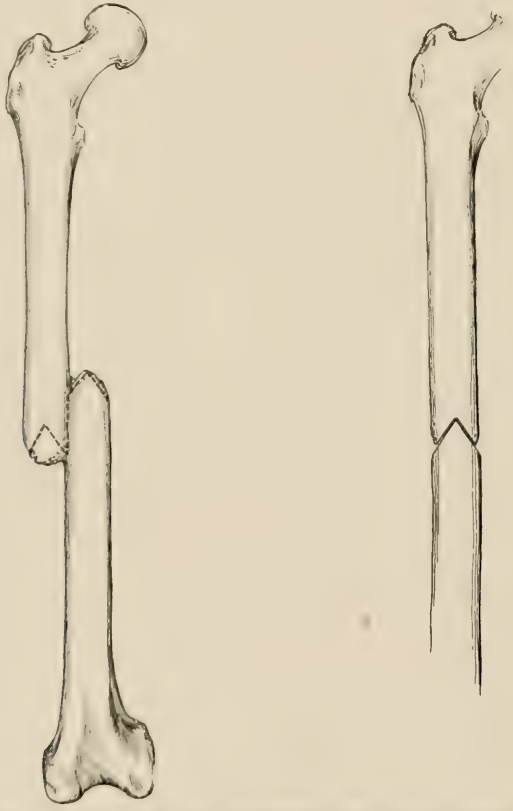
epiphysis of the adjacent bone. This is done by splitting the bone lengthwise and transplanting one-half into the defect, as suggested by H. Audree (Deutsche Med. Woch., Aug. 6, 1914). The bone is split up as far as is necessary to give a splinter or brace for the defective bone. The split-off piece is left attached to its parent bone at one end. Later a plastic may be done and the detachment completed by swinging it across to fill completely the gap of bony deficiency (Figs. 579 and 580). This principle is applicable in the tibia, fibula, radius and ulna.

Operation for Coxa Vara

The operation formerly done for this condition was osteotomy below the lesser trochanter. A better operation is osteotomy of the neck of the femur, followed by fixation of the joint with a plaster-of-Paris splint in a position of abduction. Union of the bone takes place in a corrected position. Operation is not indicated if the bone is still soft and can be corrected by forceful abduction (see Vol. III).

Operation for Coxa Valga

This condition, which is the opposite of coxa vara, is treated by the same osteotomy, but the thigh is immobilized in the adducted position. This condition does not require operation if the bone is still soft and can be influenced in its form and growth, because immobilization and weight-bearing in forced adduction will correct the deformity.



Figs. 581 and 581*A*.—Operation to Lengthen Long Bone with Vicious Union of Old Fracture.

The union is separated, the bone ends are made wedge-shaped, drawn apart, and fitted together.

OPERATIONS TO LENGTHEN BONE

These operations are usually required in the treatment of old fractures after healing with overriding. They may be done to equalize the lengths of bones or to increase height. After dividing the bone and separating the

fractured region from its soft tissues, strong traction may be applied to give the desired separation. Screws, pegs, plates or catgut ligatures may be

FIGS. 582 AND 582*A*.—OPERATION FOR LENGTHENING LONG BONE.

The sharp end of the lower fragment is caused to pierce the medullary canal. A bone graft may be used to maintain the separation.

FIGS. 583 AND 583*A*.—OPERATION TO LENGTHEN LONG BONE.

The apex of the lower fragment is caught in a notch made in the upper fragment.

FIG. 584.—OPERATION TO LENGTHEN BONE.

Showing *Z* incision made with saw.

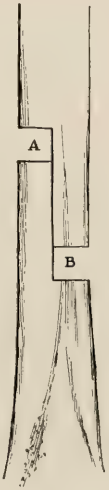


FIG. 585.—OPERATION TO LENGTHEN BONE.

Blocks of bone cut from the tibia or elsewhere are inserted at *A* and *B*.

required to hold the fragments (Figs. 581, 582, 583, 584 and 585). See Operations for Fractures, page 502, and Traction, page 487.

THE TECHNIC OF BONE-GRAFTING AND TRANSPLANTATION

Autoplastic and heteroplastic transplantation of bone or parts of bone, which have been detached from their vital connections, represent the modern and most successful employment of plastic operations for filling defects of bone. Bone-grafting is useful also in securing ankylosis of joints, in changing the contour of bones, in uniting fractures, in cosmetic surgery and in many other fields of surgery where a transplanted body may be useful.

Filling bone-defects is one of its most useful applications. The defect to be filled may be the result of osteomyelitis, tuberculosis, resection for tumor, fracture or other disease. Wherever bony tissue is missing, it may be supplied from other sources. The best results are secured by taking the piece of bone from the patient himself at the time of operation. This gives a fresh warm graft, without the danger of introducing an unknown constitutional infection or imposing an obligation upon any one.

The graft should be cut of the size and shape desired, and transferred immediately to its new bed. If a short time must intervene, it should be kept in warm normal salt solution. If the graft must be kept for several hours or days, it is best to keep it in sterile vaselin. This prevents drying. The graft should be kept in a jar of vaselin in a cold storage of a temperature of 4° or 5°C. (40°F.).

The field of operation should be prepared as for plastic operations with flaps. The field must be made sterile. The surgeon who cannot command the essential principles of aseptic surgery should not attempt these operations. Periosteum should be preserved. If the defect to be filled does not involve the whole thickness of the bone, but represents only a cavity, rough bone should be opposed to rough bone, and periosteum should be placed outside. There is no harm in burying periosteum in bone, as it will be destroyed if it does not occupy a superficial position; but it is desirable, though not necessary, that superficial surfaces should be provided with periosteum.

The bone to be transplanted should be denuded of all soft tissues. Periosteum should be left on the graft. If possible, the graft should be cut out in the size and shape needed, so that trimming is not necessary after it is removed. For long bone transplantation from the patient himself, the fibula, which may wholly be used, and parts of the tibial shaft are most available. The circular saw driven by an electric engine is best for removing the bone. The defect should be made ready, the wound covered with towels, the graft separated, and without any further treatment and with as little handling as possible placed at once into its new bed.

For holding grafts into total defects, simple suturing of the surrounding soft parts usually suffices. In some cases, fixation by pins, dowels or rings, such as are used for fixing fractures, may be required. Usually such apparatus may be dispensed with by cutting the bone-ends in such a way as to make them self-retaining.

The wound should be closed tightly throughout, fascia and muscles being replaced to support the graft. Drainage is rarely to be used. If the defect is a total one, the limb should be treated as a fracture from that time on.

In all of these operations, sterilization with chlorin or of iodin is at present the best protection against infection. Only gloved hands should participate in the operation, and these should touch the bone and wound but rarely. Sponging and manipulations should be done through the interposition of instruments as much as possible.

The patient's own tibia furnishes the most useful graft material. When holes are needed in the graft, it is best that they be bored before the bone is separated. Small chips of bone should not be wasted. They should be

placed about the graft if there is any unfilled space, or used to fill the defect in the tibia.

When bone from another person is used, the transfer should be made at the same time the bone is removed. Bone is furnished by parts which have required to be amputated, or from the recently dead provided no infective condition exists in the source of the graft which might be inimical to the patient. The two operations are sometimes done at different places, and the transplant wrapped in a warm towel, wet with salt solution, placed in a protecting envelope, and carried to the patient.

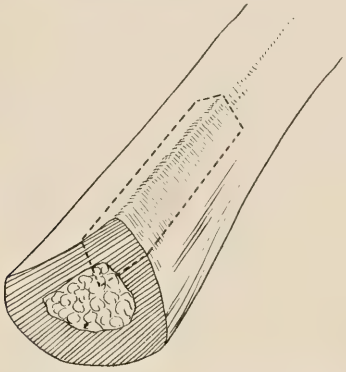


FIG. 586.—MANNER OF CUTTING QUADRANGULAR GRAFT FROM CREST OF TIBIA, HAVING PERIOSTEUM ON TWO SIDES.

As much as 14 cm. (5½ inches) of femur from an amputated thigh have been successfully implanted in another patient to take the place of that amount of bone removed for sarcoma.

Tibial Grafts.—The most accessible and useful source of grafts is the lower three-fourths of the patient's tibia. The antero-internal surface is most accessible. The shin or crest of the tibia gives the strongest graft. It furnishes a right angle, and provides a graft with periosteum on two sides

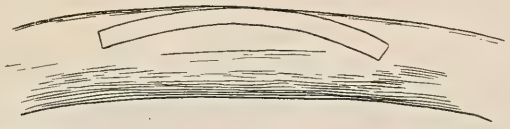


FIG. 587.—METHOD OF SECURING A CURVED GRAFT FROM THE INNER SURFACE OF THE TIBIA.

(Fig. 586). Grafts of various shapes and sizes may be cut from the flat surface (Fig. 587). The whole thickness of the cortex of the bone is used (Fig. 588).

The area from which the graft is cut should be exposed by a curved incision turning back a long flap, so that when the flap is sewed back the skin suture does not lie on the wound of the bone. Periosteum should be left on the graft.

Grafts may be cut with parallel sides or oblique sides (Fig. 589). They may be cut with a saw or chisel. The circular saw is most useful. The small circular saw best serves to divide the end (Fig. 590). A triangular graft is cut by passing the saw through the whole thickness of the bone at the shin (Fig. 591).

To hold an inlay graft in a gutter, the sides of the gutter should be bored and a suture of chromicized catgut or kangaroo tendon passed through. To prevent the transplant from coming out, both loops should pass in front of it. To prevent its falling in, one loop may pass behind it and one in front of it (Fig. 510). Usually where several sutures are applied, they may alternate,

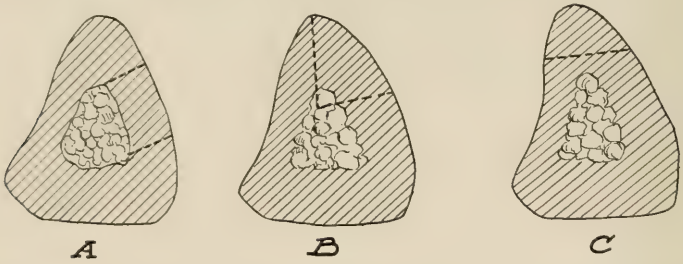


FIG. 588.—METHODS OF CUTTING BONE GRAFTS.
Showing graft involving whole thickness of cortex of tibia (*A*), graft with but little marrow surface (*B*), and graft not involving medullary canal (*C*).

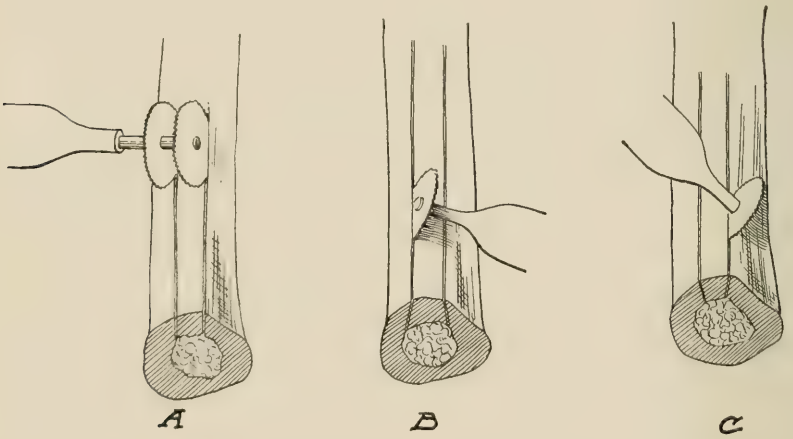


FIG. 589.—METHOD OF CUTTING GRAFTS WITH PARALLEL SIDES (*A*), WITH CENTRAL DIVERGING SIDES (*B*), AND WITH CENTRAL CONVERGING SIDES (*C*). (*After Albee.*)

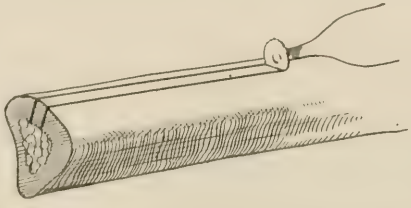


FIG. 590.—SHOWING METHOD OF CUTTING ENDS OF GRAFT WITH A SMALLER CIRCULAR SAW. (*After Albee.*)

and thus prevent displacement in either direction (see Operative Treatment of Fractures by Bone-grafting, page 509).

Instead of using sutures both the inlay and the sides of the gutter may be bored at several places, and small pegs of bone driven in. In many situations no special bone suturing is required, as the fascia or other soft tissue sewed

over the graft holds it. A most satisfactory method of fixation is by mortising. The graft is cut with a slant to its edge which prevents its escape from its bed. Pins and pegs driven into holes and canals naturally are self-retaining.

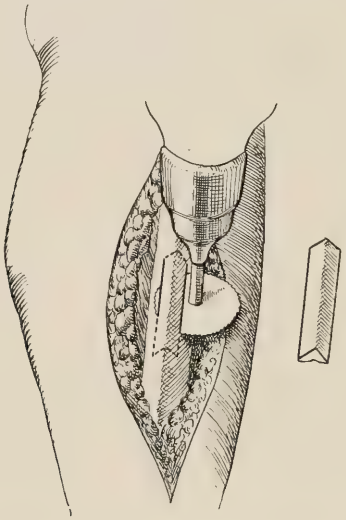


FIG. 591.—METHOD OF SECURING WEDGE-SHAPED OR PRISMATIC GRAFT FROM CREST OF TIBIA. (*After Albee.*)

Head.—Osteoplastic grafting is done about the nose and jaws to restore lost parts and change the contour (see Plastic Operations on the Face, Vol. III). Filling defects of the skull are described under Operations on the Skull.

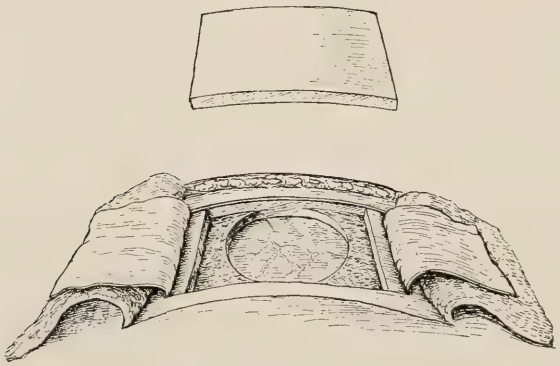


FIG. 592.—METHOD OF CLOSING DEFECT IN SKULL BY A BONE GRAFT.

Note that the scalp and periosteum are reflected; a segment is removed from the outer table only on either side of the opening. A graft of fatty fascia should be placed between the brain and the bony graft.

Autogenous Grafting for Defects of the Skull.—A graft from the tibia may be taken to fill a defect in a part of the skull in which there is not much curve. Such a graft may be cut to fit a bed provided for it by removing part of the outer table of the skull (Fig. 592). The defect should be filled with a layer

of fascia and fat to cover the dura, and the bone graft placed over all. If the graft is to be placed on a part of the skull where there is considerable convexity, it is best taken from a rib.

Spine.—*Tuberculous Spondylitis.—Treatment with a lateral spinal graft* is as follows: The patient's back and leg are prepared for operation. A general anesthetic is given. The patient lies prone on the operating table. The incision to expose the spinous processes begins at the tip of the spinous process of the third vertebra above the disease; it curves to one side of the median line as a crescent, and down to the tip of the spinous process which is the third below the disease. This is the same incision which is used for laminectomy. The skin and subcutaneous connective tissue are dissected back as a flap, exposing the spinous processes covered by their ligaments.

FIG. 593.—METHOD OF DETERMINING SIZE AND SHAPE OF GRAFT NEEDED FOR KYPHOSIS. The kyphosis is pressed forward and the curve of the spines is duplicated by a flexible probe or staff after the method of Albee.

The soft tissues and periosteum are dissected free from the side of the spines and from the posterior surface of the laminæ of the same side. A knife is passed between the spines and the intraspinous ligament removed. The upper and lower borders of the spines are freshened with a chisel or burr. The exposed sides of the spines and the posterior surfaces of the laminæ are freshened with a chisel or burr. This freshening of the bone should be deep enough to remove periosteum and bony cortex.

If there is no kyphosis, a straight graft is cut. If kyphosis is present to a considerable degree, a curved graft is useful. To determine the size and shape of the graft pressure is made on the kyphosis, and the curve duplicated with a flexible probe (Fig. 593). The wound is then covered.

The patient is left in the prone position. The leg from which the graft is to be taken is flexed acutely at the knee. The graft is best taken from the lower two-thirds of the tibia, on the antero-internal surface. A curved incision is made to turn back a flap, exposing the antero-internal surface of

the tibia over an area sufficiently large to remove the graft. The skin flap should be so placed that when the skin is sewed back in place the wound does not lie on the wound of the bone. The skin flap is dissected up from the bone leaving the periosteum on the bone. All of the soft parts excepting the periosteum should be dissected away from the bone; the muscles are pressed back from the external surface near the crest.

The probe which represents the length and curve of the graft desired is laid on the inner surface of the tibia. The outline of the graft is marked with a scalpel which cuts through the periosteum. If a curved graft is to be cut the middle of the convexity should include the crest of the tibia to bring the strongest part of the graft where it is most needed. The graft is cut with a single circular saw. The two sides of the graft should be as nearly parallel as possible. If the kyphosis can be pressed down nearly straight, a straight graft may be cut. This should be taken from the crest of the tibia. The ends of the graft are cut transversely by means of a smaller circular saw.

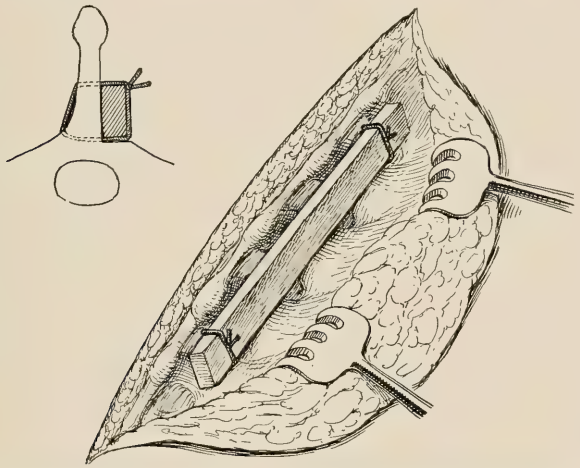


FIG. 594.—GRAFT PLACED AT SIDES OF SPINOUS PROCESSES.
The sutures which hold it may embrace the spinous processes or catch only the ligaments.

The graft should involve the whole thickness of the cortex of the bone down to the medullary canal. It may be freed by a chisel and lifted out with forceps, not being touched even by the gloved hand.

The graft is placed in the vertebral angle made by the spines and the laminæ (Fig. 594). The graft should lie against the spines and laminæ of the two vertebræ above and the two vertebræ below the diseased vertebra. A chip of bone should be wedged between the spines. The graft is held in place by a suture of kangaroo tendon at either end and by suturing the soft tissues over it. The sutures may pass around the spines or catch only the soft tissue. The pressure of the mass of muscle and fascia which is dissected from the bones, when it is replaced, suffices to hold the graft. The deep structures should be strongly sewed over the graft. In order to do this, it is necessary to make an incision in the fascia external to the wound to permit the fascia to be drawn over the graft and attached on the other side. The skin should be closed by a separate suture.

Treatment with a graft inlaid in the split spinous processes is best applied by the operation perfected by F. H. Albee. The curved incision described

above is made and the spines exposed. The supraspinous ligament is split in the median line and the scalpel is also passed down between the spines splitting the interspinous ligaments. Then with a thin broad sharp osteotome the spinous processes are split exactly in the median line for a distance of 1 to 2 cm. ($\frac{3}{8}$ or $\frac{3}{4}$ inch). The spines of the diseased vertebra, the two

FIG. 595.—SHOWING METHODS OF SPLITTING AND FRACTURING SPINOUS PROCESSES TO RECEIVE GRAFT. (*After Albee.*)

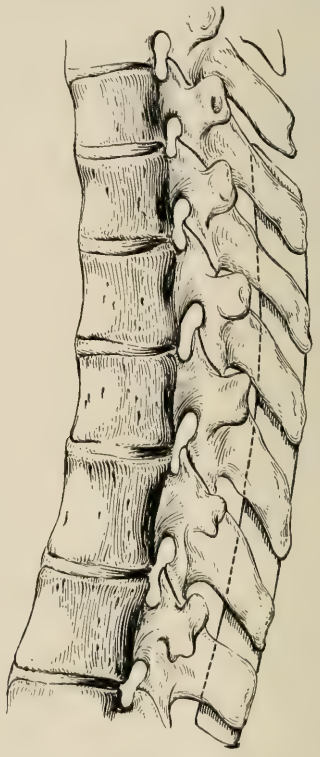


FIG. 596.—GRAFT IN PLACE IN THE SPLIT SPINOUS PROCESSES.

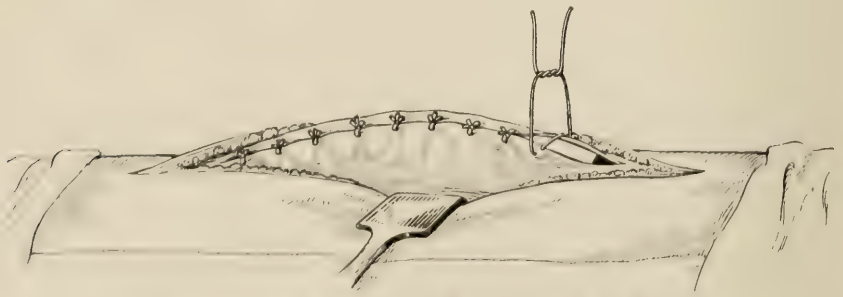


FIG. 597.—ALBEE'S METHOD OF FIXING GRAFT BY SUTURES.

vertebræ above, and the two vertebræ below should be split. One side of the split spine should then be fractured at the bottom of the split. This should be done on the same side with all of the split spines. The gutter thus formed should be packed with a compress soaked with warm salt solution. The graft should then be cut from the tibia as described in the above operation.

The gauze packing is removed from the fractured spines and the graft is deposited in the cleft (Fig. 595). The graft should include two healthy spines above and below the disease. If a narrow graft is used, the one-half of the spine will need only to be fractured. If a wider graft is used, half

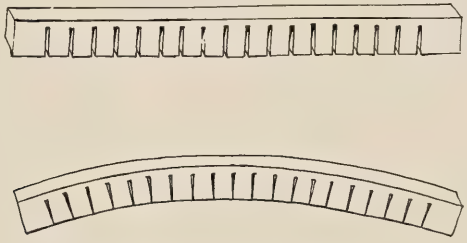


Fig. 598.—Albee's Method of Making Curved Grafts by Multiple Transverse Saw Cuts to Permit Bending.

of the spine will need to be fractured and slightly displaced (Fig. 596). The graft is held in position by passing a suture of kangaroo tendon through one-half of the split supraspinous ligament close to the middle spine at one side of the gutter. The suture then passes over the middle of the graft and

Fig. 598*a*.—Shaping Graft to a Kyphosis after the Method of Henderson.

through the other split half of the supraspinous ligament on the opposite side. The suture is tied tightly, drawing the split ligament over the graft. The next sutures are applied similarly at the ends. These sutures are applied above and below each spine, and in this manner the graft is buried (Fig. 597).

In adults the ligaments may be so unyielding that the sutures must be placed midway between the spines in order to make the wound meet over the

graft. Or it may be necessary to make an incision in the vertebral fascia on either side of the wound in order to secure apposition to cover the graft. If the angular ends of the graft are prominent, they should be rounded off with the ronguer and the bone chips planted in the split.

Albee made curved grafts by cutting a straight piece of bone from the tibia, and then making multiple transverse cuts three-quarters through the graft. Such a graft may be placed in position and bent with the cuts in its concavity. It is especially useful in extreme curvatures (Fig. 598).

Grafts for thus immobilizing the spine may be placed at any part. In the cervical region a much lighter graft suffices than is required lower down. Where curved grafts are not needed, but only an angulation is desired, a small wedge cut from the graft permits it to bend (Fig. 598*a*).

FIG. 599.—SPINOUS PROCESSES FRACTURED AND DISPLACED DOWNWARD TO PRODUCE ANKYLOSIS AFTER THE METHOD OF HIBBS.

Spinous process ankylosing is the operation devised by R. A. Hibbs, and first described in 1911 (New York Med. Jour., May 27, 1911). A median incision is made over the spinous processes down to the tips of the bones. The periosteum is split along the upper and lower borders of each spine and the laminæ. The periosteum and soft tissues are pressed back as far as the bases of the transverse processes. The spinous processes are then partially fractured with a chisel and bent down so that they make contact with fresh bone. At least two vertebræ above and two below the diseased bone should be operated upon. This means at least five spines (Fig. 599). The base of each remains connected at its own base and the tip comes in contact with the broken base below. A small piece of bone is elevated from the edge of each lamina and placed across the space below it, so that it rests on the lamina below. The lateral articulations are exposed and the articular cartilage removed with a small curet.

The periosteum, which has been reflected laterally with the soft tissues, and the split supraspinous ligament are sewed together at the median line, over the processes, with kangaroo tendon or chromic catgut interrupted sutures. This operation results in a callus which binds together the vertebræ.

The *indications for operative treatment* seem to be almost without limit. All cases at all ages in which tuberculosis is rarefying the vertebra and causing pain and muscular spasm may be benefited by it. The earlier the operation is done, the better is the prognosis. The presence of complications, such as psoas spasm, pure tuberculous abscess, kyphosis and paraplegia, not only do not contra-indicate but call for the operation. Cases with cold abscess and sinuses seem to heal kindly. Grafts which were bathed in the pus of tuberculous abscesses have healed without exfoliation.

The indications for treatment by bone graft and bone plastic fixation

are practically the same as for all forms of fixation. Operation is applicable to all cases in which immobilization and support are needed. If the patient has enough reparative power to recover from the disease, he has enough reparative power to heal in a transplant of healthy bone or develop callus. The earlier in the disease the operation is done the better is the reparative power and the less is the deformity. These operations offer the best hope for the prevention and correction of deformity. They are not only not contraindicated but are positively indicated in the presence of progressive deformity.

The *contraindication* to this operation is the inability to secure a clean field of operation. This is rare because the tubercular abscess does not

FIG. 600.—METHOD OF RESTRAINING PATIENT AFTER OPERATION FOR SPONDYLITIS.

tend to invade the region of the spinous processes; and even though it does, bone-grafting is not contraindicated. In some cases in which such abscesses have been encountered unexpectedly, the grafts have healed in place.

The *choice of operation* depends much upon the location of the disease. The spine-ankylosing operation of Hibbs is especially useful in the middle and upper dorsal and cervical regions because of the length and shape of the spinous processes. Bone transplant operation is to be preferred in the lower dorsal, lumbar and sacral regions. Cases in which there is a pronounced kyphosis with separation of the spines are best treated by the bone transplant method.

The *after-treatment*, following these osteoplastic operations for spondylitis, is the same for each. The wound should be closed and dressed and the patient should lie on a fracture bed. The patient should lie quietly in the recumbent position on a hard mattress, placed on a board, for five or eight weeks. The only restraint usually required consists of a towel around the body, to which are fastened four strips of muslin, two of which lie over the shoulders, passing

to each of the corners of the bed (Fig. 600). The object of this is to prevent the patient sitting up or rolling on his side. This is not needed in the case of adults. A thick pad should be placed on each side of the spine to take pressure from the seat of operation. In cases of pronounced kyphosis, the patient must be placed on his side. The plaster jacket usually is not necessary until the patient gets up, and weight-bearing falls upon the spine; and even then it is not always required.

Adults usually require no restraint. If there is kyphosis, it should be protected by pads at either side of the spine. Pressure upon the wound must be avoided lest necrosis of the skin flap occur.

If there is any question about keeping the patient quiet, a posterior plaster splint should be moulded to the patient while lying prone on the operating table. This should extend from the head to the bottom of the pelvis. Or, still better, this splint may be made before the operation, a pad of gauze to imitate the dressing being introduced.

The general hygienic treatment should be continued. At the end of five or eight weeks the patient is allowed up. Artificial external support is usually desirable when the patient gets up. In exceptional cases support may be dispensed with. Extreme kyphosis which required a much curved graft, and cases which have to leave the hospital before five weeks have elapsed, must always be provided with a plastic jacket for a time.

It is desirable that at least six months of postoperative convalescence should elapse before the patient takes up active work. During this time some external support is advisable. It is possible in some cases for adults to return to work in two months. Children should have outdoor life for fully a year after operation.

Hibbs preferred to apply a steel brace immediately after operation and require absolute rest in bed for eight weeks. The patients are allowed to sit up for four weeks. Walking is allowed at twelve weeks; and the brace is gradually removed at sixteen weeks.

The results of osteoplastic treatment, after bony union has taken place, are immobilization of the diseased segment of the spine, and the benefits which arise from such immobilization. This is the aim of treatment by plaster-of-Paris jackets. The disease itself is not changed. For this reason, immediately after the operation, the patient should be put out of doors, and the antituberculous measures applied. Six months should elapse before the patient resumes heavy work or active life. Children should be protected from strain for a year. Albee reported cases in which adults returned to work six and eight weeks after the operation and seemed to sustain no harm. In some cases no external support is needed during convalescence, but usually too much reliance should not be placed upon the strength of the graft. A jacket to give external support should be worn for about six months while the graft is developing callus and growing strong. If external support is not worn there is danger of increasing deformity.

Conclusions.—These operations are neither difficult nor severe, and are destined to supplant to a large degree the treatment by immobilization by external splints alone. Pulmonary tuberculosis need not be regarded as a contraindication. Young patients do better than adults. Too much dependence should not be placed upon the sustaining power of the callus or graft, but external support should be used. Such support for a few months is no reflection upon the success of the operation.

Paralytic Scoliosis.—In this condition after the acute disease has gone, and left the muscles paralyzed, and corsets, massage, and gymnastic exercises have done all they can, and no further improvement is attained, the spine

may be fixed by a bone graft to hold what has been secured. By the end of two years the surgeon should decide whether more may yet be gained or whether bone graft may be used. Grafting may be done in the spinous processes, as for spondylitis, or in the transverse processes. The latter is to be preferred.

A pad, the size of the wound dressing is fixed over the area of operation, and a plaster-of-Paris jacket is applied. This jacket is cut off in halves, by being divided on either side in the axillary line. In applying this jacket the patient should be held with the spine in a corrected position. A few days later the operation is proceeded with. A cresentic flap is turned back and the line of transverse processes exposed on the convex side at the place of the greatest curvature, six or eight are split and the outer halves of the split processes are fractured, as described for spondylitis. A graft is cut from the whole cortical thickness of the tibia and placed in the split. The patient is placed in a corrected position. The wound is sutured and dressed, and the already made plastic jacket is applied. The patient is kept recumbent in the plaster jacket six weeks. Then another plaster jacket is put on and left for ten weeks or more while the patient goes about. At the end of that time exercises should be resumed, but they must not aim to bend the spine at the site of the graft.

Spondylolisthesis.—This condition of luxation of the body of a vertebra, occurring usually in the lumbar region, is amenable to spinal grafting such as is used in spondylitis. The displacement is corrected under general anesthesia as the patient lies prone on the operating table. Lordosis may require that a pillow be placed under the abdomen. A strong graft should be used, and placed so that it embraces two vertebræ above and two below the displaced segment. This may require extending the graft upon the sacrum.

Spina Bifida.—This condition may be operated upon by placing a graft on either side of the cleft caused by the absence of laminæ and spines. To completely cover the opening a flat piece of bone may be placed over it in the median line. The graft should be held by suturing the fascia over it.

Sacro-iliac Joint.—*Tuberculosis* may be treated by a bone graft passing between the sacrum and ilium.

Dislocation or *relaxation* in intractable cases may be treated by placing a longitudinal graft of bone along the posterior aspect of the joint in such a manner that it lies in a denuded gutter one side of which is ilium and the other side sacrum.

Hip.—*Habitual, Paralytic and Congenital Dislocation of the Hip-joint.*—These conditions should be treated by remedying the causative disease. Manipulations and stretching contractured parts may be expected to cure most cases. Cases which do not yield to these measures, and in which the head of the femur persists in riding up out of its socket (Fig. 601), may be cured by osteoplastic operation. The old operation done for congenital dislocation of the hip by Hoffa (page 616) often resulted in ankylosis or a painful joint. Albee later devised an operation whereby wedges of bone from the tibia are transplanted to serve as an upper wall to the acetabulum, and thus prevent riding upward of the femoral head. Before performing such an operation all contractures which limit the mobility of the joint should be overcome by stretching gradually with weights, by forcible stretching under general anesthesia, or by division with the knife.

An incision is begun at the anterior-superior spine of the ilium and carried to the top of the great trochanter, thence it curves backward for 3 or 5 cm. (1 or 2 inches) toward the tuberosity of the ischium (see Exposure of Hip-joint, page 748). The flap of skin and superficial fascia is dissected back and

the trochanter exposed. The tip of the trochanter with its muscular attachments undisturbed is sawed off and reflected upward. This gives a view of the upper and back parts of the capsule of the joint as far as the rim of the acetabulum.

The bone above the rim of the acetabulum is then cleared of soft tissue. With a narrow osteotome a semicircle is cut in the bone above the acetabulum close to the capsular ligament (Fig. 602). This postero-anterosuperior lip of the acetabulum with its attached capsule is pried outward and downward to overhang the head of the femur and deepen the socket. The upper part of the capsular ligament which is already relaxed by the disease is still more relaxed by this step in the operation. The slack is taken up by applying a row of chromic catgut sutures (Fig. 603).

FIG. 601.—CONDITION TO BE REMEDIED IN CONGENITAL AND PARALYTIC DISLOCATION OF HIP.

Note that the relaxation of the capsular ligament and the erosion of the upper rim of the acetabulum permit the head to ride upward out of the socket. (*After Albee.*)

FIG. 602.—OSTEOPLASTIC OPERATION FOR DISLOCATION OF HIP.

The tip of the great trochanter has been cut across and reflected upward with its attached muscles and the osteotome cuts the upper rim of the acetabulum. (*After Albee.*)

The gap in the bone above the socket is filled with bone transplant. For this purpose a triangular piece of bone is cut from the crest of the tibia. This should be long enough to be cut into three or four pieces which will fill the gap. Before the piece is removed from the tibia, small drill holes should be bored in the graft at such positions that when it is cut into pieces, each piece will have a hole. These triangular pieces are placed in the gap, and pinned by autogenous pegs cut from the tibia. The pegs should penetrate the cancellous pelvic bone for 1½ or 2 cm. (½ to ¾ inch). The pegs are not necessary in all cases as the grafts may be held by the soft tissues sewed over them. The tip of the trochanter with its attached muscles is then replaced, and sewed to the soft tissues with chromic catgut or kangaroo tendon. The limb is put up in the abducted position with plaster-of-Paris from the chest to the toes. This is left on for six weeks, at the end of which time it is replaced by a pelvic splint. Three months after the operation the splint is removed, and passive motion and massage applied, and careful use of the limb begun.

Restoring Head of Femur by Grafting Astragalus.—The astragalus should be secured from the foot of another person. It may be kept in cold storage immersed in sterile vaselin at a temperature of 4° or 5°C. (40°F). The hip

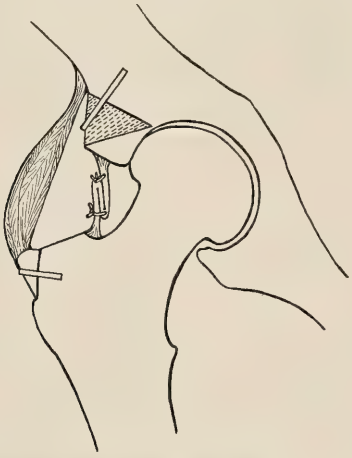


FIG. 603.—RESULT OF OSTEOPLASTIC OPERATION FOR CHRONIC UPWARD DISLOCATION OF HIP.

Note that the upper lip of the acetabulum has been turned downward; the gap has been filled with bone graft, held with bone peg; the capsular ligament has been shortened by folding and suture; and the tip of the great trochanter with its attached muscles has been held in place on the outer aspect of the trochanter by a bone pin. (*After Albee.*)

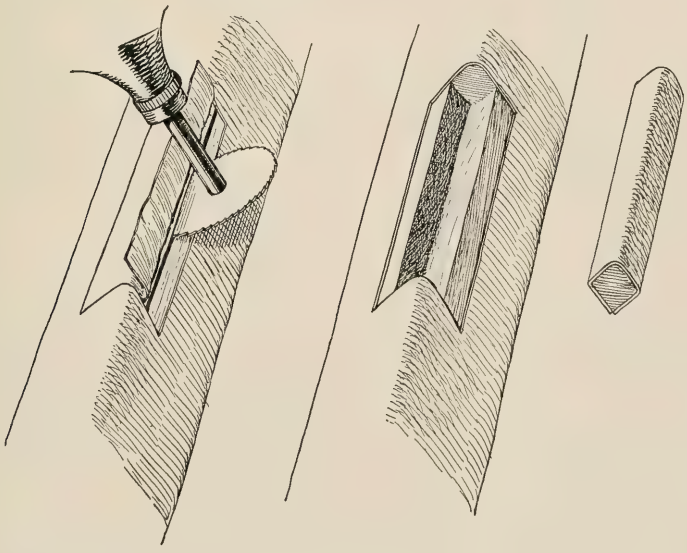


FIG. 604.—METHOD OF CUTTING GRAFT FROM TIBIA IN SUCH A MANNER AS TO COVER IT WITH PERIOSTEUM.

joint is best exposed by an anterior-external incision, beginning below and internal to the anterior-superior spine of the ilium, passing just below the great trochanter, and thence curving backward. The tip of the trochanter

is divided with the saw, and with its muscular connections turned upward to expose the joint. The capsule is split in the direction of its fibers. The neck of the femur is trimmed to receive the new bone. The astragalus to be fitted is cut so that its articular end lies in the joint socket. A pin of bone is passed through the great trochanter and the neck and into the new head as is done in treating fracture of the neck of the femur (page 512). The shape of this bone adapts it admirably for this purpose, and it must often be removed for paralytic club-foot. The forward end fits the acetabulum, and the rear end is easily shaped to be fastened to the shaft of the femur by means of a bone or ivory peg or nail.

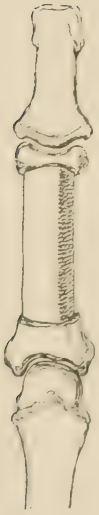


FIG. 605.—GRAFT FROM TIBIA, COVERED WITH PERIOSTEUM, INSERTED FOR RECONSTRUCTION OF SHAFT OF PHALANX IN FINGER.

FIG. 606.—METHOD OF CHANGING SHAPE OR DIRECTION OF BONE.

This operation may be used to correct bow-legs or knock-knee. It is the principle employed in osteoplastic operation for club-foot. An osteotomy is done, and a transplant of bone is placed in the fracture gap. (*After Albee.*)

Phalanges.—Transplantation of bone into the *finger phalanges* has been successfully practised to restore the loss after tuberculosis or osteomyelitis. New bone may be secured by taking a toe phalanx. When a longer piece is required, it is best taken from the tibia. Periosteal covering should be left on the graft. A lateral incision is made in the finger. The graft should restore the normal length of the phalanx (Figs. 604 and 605). To

relieve the graft of pressure the finger should be put up with extension for four weeks (see Fractures of Phalanges, page 580). If either epiphysis is gone, the raw end of the graft may be covered with fascia and fat and an articular end made (see Reconstruction of Joints, Arthroplasty, page 757).

Knee.—*Bony Ankylosis with Deformity.*—The common flexing deformity seen with bony ankylosis of the knee is best treated by arthroplasty to break up the ankylosis and reconstruct the joint. But when an ankylosis in a

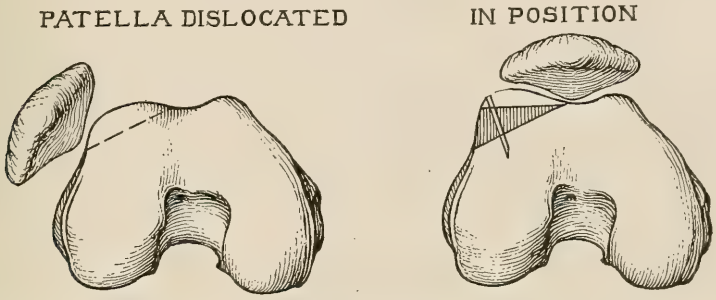


FIG 607.—OPERATION OF ALBEE FOR HABITUAL DISLOCATION OF PATELLA.
An osteotomy is done and a wedge-shaped graft is pinned in the gap, thus elevating the front of the condyle and preventing dislocation.

better position is desired, a wedge may be removed, and with the material of the excised wedge an inlay may be constructed to hold the bones and guarantee secure fixation.

Bow-leg deformity may be remedied by transverse osteotomy of the tibia, and inserting a bone graft into the chink to make the desired correction (Fig. 606).

Habitual Dislocation of Patella.—Albee split up the front of the condyle over which the dislocation occurs, elevated it until a wedge-shaped opening is produced, inserted a wedge of bone cut from the tibia and held it with a bone pin (Fig. 607). This operation should be combined with operation on the soft parts to shorten the fascia which holds the patella in place.

MUSCLES, TENDONS, FASCIÆ AND BURSÆ

MUSCLES

Contusions

Contusions of muscle, if severe enough to give rise to symptoms of disability, are associated with multiple microscopic wounds represented by separations of muscle fibers and ruptures of small blood-vessels. The blood-supply of muscles is so abundant that absorption of extravasation and healing of the minute wounds take place rapidly. The first essential of treatment is rest, just as in any wound. When coagulation of the extravasated blood has taken place, after a few days, its absorption may be hastened by hot applications or massage.

Contusions of muscles of the extremities are best treated by splints or bandages, immobilizing the joints over which the injured muscles operate. If seen by the surgeon immediately after the injury, further extravasation may be checked by a compressing pad of gauze or cotton held by a bandage to make broad and even pressure. Hematomata if not absorbed within a reasonable time should be incised and evacuated. The soreness, persisting after contusions, is best treated by rest of the muscle and massage.

The contusions caused by fractures secure the necessary rest in the treatment of the fracture. In contusions from external forces, the injury to the skin and connective tissue is apt to be greater than that sustained by the muscle. As these superficial structures are much more prone to sloughing and infection than is the more sanguineous muscle, their vitality should be conserved. Cold applications are objectionable. The skin if dangerously contused should be cleansed and covered with a warm antiseptic dressing, with the view of preventing infection and sloughing which might extend to the underlying damaged muscle.

Rupture of Muscle

There are all degrees of rupture of muscles. The slightest ruptures require the treatment described under contusions—rest and later massage. Gross ruptures of bundles of muscle fibers, involving a small part of the whole muscle, are best treated by adhesive plaster strapping applied in such a way as to give pressure and immobilization. In all cases it is desirable to place the parts in such position as to give relaxation of the muscle. This is the treatment called for in the ordinary case of "tennis leg," in which there is a partial rupture of the calf muscles, or in "rider's thigh," a similar injury to the adductors of the thigh. At the end of a week, massage should be used to hasten absorption of exudate. Ruptures of muscle, in which the lesion is great enough to be felt or seen, or to cause a decided change in the contour of the limb, or in which a muscle is torn in two, are best treated by myorrhaphy.

Myorrhaphy, the sewing of muscle, should be done as soon as possible after the injury. The divided muscle is exposed by an incision parallel to its fibers. Blood clots should be removed and hemostasis secured. Ragged edges should be trimmed. The limb or parts should then be placed so as to

relax the muscle, and the sutures applied. A continuous absorbable suture such as chromicized catgut is most useful. The needle should be passed deeply, otherwise the suture is apt to pull out. All of the separated fibers should be approximated. If the gap is large this requires more than one row of sutures. A few deeper interrupted or mattress sutures may be called for. The overlying fascia should be included in the most superficial sutures to give additional security (Fig. 608). An immobilizing dressing should be applied and the part kept at rest with the muscle in relaxed position for three weeks. After this, use of the muscle may be carefully begun.

In cases in which the muscle has been torn loose from a bone or at its connection with a tendon, there may be but little material to which to suture the muscle. Under such circumstances a flap of fascia should be taken from near the wound and used to patch or strengthen the connection.

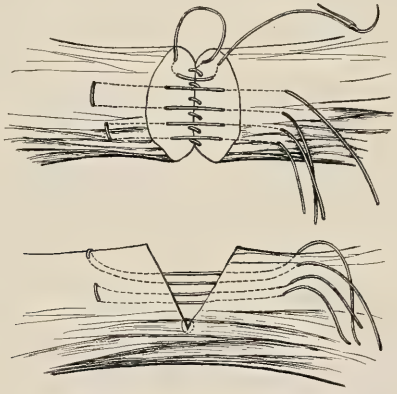


FIG. 608.—SUTURE OF MUSCLE.

Note mattress sutures to give especial security, combined with running suture.

Operation done for *old rupture* may find the muscle so contracted that it cannot be made to come together. Under such conditions, a pedunculated or detached patch of fascia may be used to bridge the gap, the stump may be sewed into an adjacent muscle or the tendon may be lengthened. Muscle stumps should not be left contractured and curled up; they should always be straightened out and sutured into something. If the muscle is ruptured in the middle, and cannot be brought together, either immediately or by the intervention of a flap of fascia, each stump may be sutured into the adjacent muscle.

In the case of *rupture* of the long head of the *biceps* at its upper tendinous juncture, the muscle may be sutured to the tendon and the suture line strengthened by wrapping about it a flap of fascia taken from the front of the short head. In a case in which five months had elapsed since the rupture, and the belly of the muscle could not be made to reach to its tendon from which it had been torn, P. S. Doane (Jour. Am. Med. Assoc., May 16, 1908) split the upper part of the short head, and sutured the wounded end of the long head into it (Fig. 609).

HERNIA OF MUSCLE

Hernia of muscle which is small and causes no annoyance requires no treatment. If it interferes with function or produces discomfort it should be operated upon. The hernia is exposed by an incision parallel to the

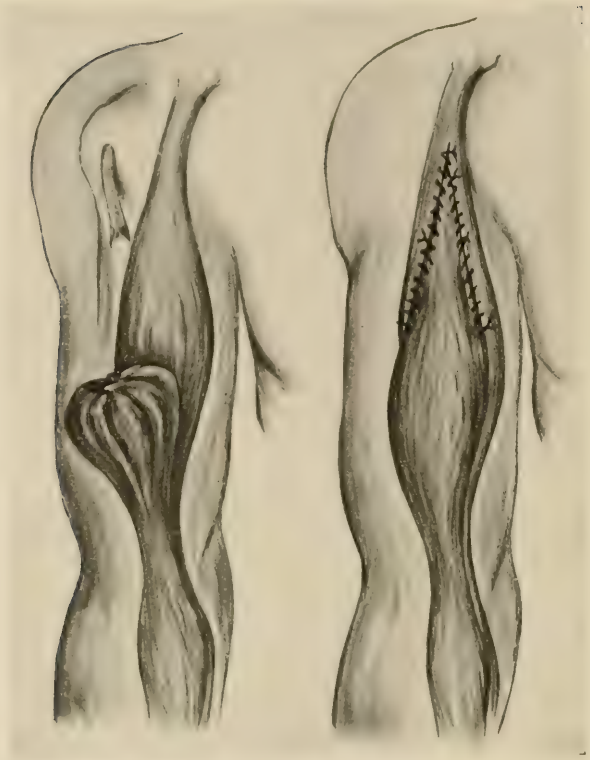


FIG. 609.—OPERATION FOR RUPTURE OF LONG HEAD OF BICEPS CUBITIS.

FIG. 610.—HERNIA OF MUSCLE TREATED BY RESECTION OF HERNIATED PORTION, SUTURE OF MUSCLE WOUND, AND CLOSURE OF FASCIA.

muscle. If the hernia is old it will be necessary to excise the part of the muscle which protrudes through the sheath. In the case of a recent hernia the muscle may be pushed back. The sheath should be loosened from the muscle for a short distance around the hernial opening, and the opening in the sheath closed. In some cases it is necessary to excise the protruding muscle. The herniated part of the muscle having been excised, and the muscular wound sutured, the fascia should be united by an overlapping suture (Fig. 610).

Wounds of Muscle

Open wounds of muscle which divide muscle bundles transversely, require myorrhaphy, as described above. If the wound is large, the use of interrupted stay sutures, to relieve tension, is important. Unless such wounds are sutured the gap becomes filled with scar tissue which decidedly interferes with the function of the muscle.

When a muscle is so badly damaged that the gap cannot be closed, a flap of fascia should be used to connect the separated parts of the muscle. If this cannot be done and its function is an important one, the tendon of another muscle having similar action may be implanted at its insertion; or, if the nerve supply has not been destroyed, the distal stump of the muscle may be sutured into the belly of another muscle. Such an operation may be done with the proximal stump also when it is desired to preserve the strength of the part as much as possible. Later after the proximal stump has resumed function with the muscle into which it has been sutured, the insertion of the latter may be transferred to the site of insertion of the damaged muscle. These latter expedients are rarely called for, because the transplantation of fascia can be made to meet most requirements (see Transplantation of Fascia, page 758, Vol. I; and Vol. III).

Cicatrix of muscle, resulting from the healing of an unsutured gap, may require excision and suture of the muscle. Usually when such scar tissue is excised a gap will be left which can not be closed without producing shortening of the muscle. Excision of such scar tisssue is called for then when it is the cause of pain, or when a myoplastic operation, such as is described above, is contemplated. For adherent or painful scar, massage will often give relief.

Infections of Muscle

Muscle is so well supplied with blood that infection does not often require to be treated.

Infective myositis requires the same treatment as other infections. *Primary infectious myositis*, occurring in debilitated patients, should be met by general hygienic treatment, free incision and drainage of the infected muscle. The treatment of *acute polymyositis* must be directed to the general hygiene of the patient; and local disturbances met as they arise (see Cellulitis, page 264).

Gangrene of muscle occurs in debilitated persons. I have seen it usually associated with improperly applied dressings in fractures. Bandages, causing impairment of circulation, and the superaddition of infection, result in the intermuscular plains becoming invaded by infection which causes thrombosis in the supplying vessels and gangrene of the muscle. Isolated muscles in such cases may be grasped at one end and pulled out of their beds. This condition may occur in the cases of simple fractures put up too tightly, the infection entering through a slough of the skin. In the treatment of

fractures this possibility should be had in mind. Sloughing muscles should be removed and drainage provided.

Tuberculosis of muscles occurs by extension from neighboring foci or by metastasis. The treatment should be conducted upon the principles already described (see Tuberculosis, page 276). The high degree of resistance against infection possessed by muscle means that there is poor bodily resistance when tuberculosis develops in this tissue. Therefore, time should not be lost in tentative measures but the disease eradicated as soon as possible. The operation should be complete. Tuberculous nodules should be exposed and removed. As much of the muscle as is diseased should be dissected out. If necessary the whole muscle should be removed. An isolated tuberculous abscess may sometimes be dissected out as a tumor without opening it. If the abscess is irregular in shape, it is best treated by evacuation through a needle or trocar and the injection of medication into the sac, or by freely laying it open (see Tuberculous Abscess, page 281).

Following the excision of muscles a myoplastic operation may be required to preserve function (see Wounds of Muscles, page 791). Such an operation may be done at once or later after the resistance of the patient has been improved.

Syphilis of muscle requires no especial local treatment. Specific medication must be relied upon. Later treatment of contractures may be required (see Syphilis, page 283).

Actinomycosis of muscle is treated the same as in other structures. When possible the whole diseased area should be excised as a tumor (see Actinomycosis, page 272).

Trichinosis should be prevented. When an individual has eaten trichinous pork, before the embryos have been hatched and penetrated the intestine, a laxative and anthelmintic should be administered as soon as possible. Even after invasion of the muscles a purgative should be given to prevent further possible infection. The disease is self-limiting. The treatment consists in sustaining the strength of the patient and meeting symptoms as they arise. Later, small painful nodules in the muscles may be dissected out.

Myositis Ossificans

Chronic ossifying myositis, the progressive infiltration of muscle with bony material, has not yielded to any treatment. If the condition is painful, patches of the osseous deposit may be dissected out of the muscle.

Traumatic ossifying myositis, the deposit of bone at the site of irritation, is best treated by dealing with the bony matter as a tumor and excising it.

Tumors of Muscle

Benign tumors which are large enough to be noticed by the patient or which produce symptoms shou'd b: excised. Mal gnant tumors should be removed along with enough healthy muscle to insure total extirpation of the disease. The malignant tumor most commonly found in muscle is sarcoma, the safest treatment of which is removal of the whole muscle; and if the bone or great vessels are encroached upon, excision of these or amputation is the operation of choice.

Degeneration of Muscle

Muscular degenerations are due to local destructive influences affecting directly the muscle cells and to trophic changes depending upon disorders of the nerve supply or circulation. The prophylactic treatment of these con-

ditions is in the domain of the surgeon. The prevention of atrophy is dealt with largely in the chapters on the nerves, bones and joints. In the treatment of all surgical conditions it is important to avoid tight bandages and other compressing apparatus, excepting when especially called for. Muscles should have their wonten exercise or massage or electricity in its stead. The faradic current may be used to take the place of exercise if the nerve supply is intact. Galvanism is of value to keep alive the muscular tone when the nerve supply is shut off.

Atrophied or paralyzed muscles should be kept in such a position as to relieve them from tension. When a group of muscles, say the extensors of a joint, becomes paralyzed, the flexors will have unopposed power to flex the joint and ultimately to become spastic. It is important in such cases to keep the joint in the extended position. Often in permanently paralyzed muscles it is possible to suture their tendons of insertion into some adjacent, healthy muscle, and thus secure restoration of function. Or the tendon of another muscle may be transplanted into the place of insertion of that of the paralyzed muscle (see Atrophy and Paralysis of Muscles).

Contractured muscles occur in connection with a joint not kept in a corrected position when a group of muscles operating it become ineffective. To correct bad position of the joint the contractured muscles must be stretched, divided or an osteotomy performed. Stretching such muscles is facilitated by the local use of moist or dry heat or by means of artificial hyperemia while stretching movements are applied. Such treatment may be given for an hour or more daily. Elastic stretching, by means of rubber elastic or a spring applied in such a way as to make constant traction upon the contractured muscle, is of service in many cases. Forcible stretching under narcosis is sometimes useful. Open division of the muscle and fascia is of service in some cases in which the contractured muscle has degenerated, especially if a myoplastic operation can be done to supplement the damaged muscle (see Joint Malpositions Due to Contractures of the Soft Parts, page 682).

The treatment of paralytic contractures should be begun as early as possible. The aim should be to prevent contracture. After anterior poliomyelitis the limbs should be kept in position by the artificial application of some force to counteract the unopposed muscles, and to take the place of the paralyzed muscles. The nourishment of the parts should be kept up by the stimulating measures above described.

Ischemic degeneration of muscle which commonly follows injuries such as traumatisms, fractures and dislocations, and is observed in the extremities, is more commonly a result of the treatment than of the injury. So long as the fascia and skin may stretch to accommodate the swelling, incident to the effusion of serum and blood elements, no harm ensues; but when bandages are applied which prevent this swelling, in from six to forty-eight hours the compression of the vessels becomes so great that the circulation stops and the muscles suffer degeneration because of the shutting off of their blood-supply. Usually involving the flexor muscles alone, and rarely associated with paralysis of motor or sensory nerves, this condition requires treatment addressed especially to the flexor muscles and their tendons. It is obvious that, as the surgeon is the cause of the disease, *prophylactic treatment* is the most important. Circular bandages should be avoided always. Bandages should be applied obliquely and not so tightly as to prevent the natural stretching accommodation of the skin to swelling. This applies also to splints and plaster cases.

In injuries at the elbow the joint should not be put up in acute flexion immediately after the injury unless that position is necessary for correction.

Displacement should be corrected. It is always wise to leave the joint immobilized in the most comfortable position for the first day or two. The surgeon should never allow a painful limb, with defective circulation, after fracture and dressing, to go out of his sight.

The cyanosis which characterizes the beginning of the disturbance should subside as soon as the bandages can be gotten off and the limb elevated. If it does not clear up promptly the superficial layer of the deep fascia of the limb should be incised In the forearm this may be done subcutaneously with a tenotome. The instrument is passed through the skin, and the fascia on the anterior ulnar side of the forearm divided in one or two places for a distance of 8 to 15 cm. (3 to 6 inches).

Putting the limb in the hot oven, applying hot compresses, and massage may be tried, but usually it will be found that if the removal of the bandages and incision of the fascia do not restore the muscles nothing will. This is because the damage is done so quickly. No bandage is so necessary that the danger of ischemic degeneration should be incurred. When circulation is restored the bandages or splints may be reapplied.

For the flexor contractions which follow the degeneration of the muscles many remedies are available. A splint may be applied to the forearm and hand which has a bend to accommodate the flexed wrist. The fingers should be fixed to the splint with traction apparatus so as to make gradual extension. By maintaining the traction on the fingers, the flexion at the wrist may be overcome gradually by bringing the splint toward the straight position. After hyperextension of both wrist and fingers has been secured, massage is useful.

In some of these cases constant traction upon the shortened muscles will accomplish much. To be of value the traction should be continuous and elastic.

Elongation of the tendons is the most satisfactory operation that can be done to meet the flexor contraction when traction fails. This must be done with all the tendons of the contracted muscles. It is a much more reasonable procedure than to resect the bones, shorten them and shorten the tendons of the extensor muscles. The operation should be deferred until any fracture which is present has united and the acute symptoms have subsided. This is usually two to four months after the injury (see Operations for Tendon Elongation, page 799). After lengthening the tendons, if the joint does not easily fall into the position of extension, it is necessary to divide the anterior capsule of the joint and the adjacent fascia. This may be done in the wrist, elbow or other large joints.

In later cases in which the tendons have become adherent to deep structures and bones of the forearm to such a degree that elongation of the tendons cannot be done, then resection of a segment of the bones to make them shorter becomes necessary. The tendons at the same time should be dissected in mass from the bone and a flap of fascia placed beneath them to prevent their readherence. Such a flap may be taken from the adjacent region or it may be a detached flap taken from the outer side of the thigh. If the superficial tendons are adherent to the skin the flap should be placed in front of the tendons as well as behind them. Following this operation, the loosest possible dressing, or no dressing at all, should be applied. At the end of ten or fourteen days careful passive motion should be begun. Voluntary motion may be attempted. Massage may be instituted at the same time. Pain should not be caused by any movement.

The treatment of ischemic contractures by means of apparatus applying gradual extension is used with success in some cases. Such apparatus must be

well padded to prevent pressure necrosis. Elastic traction or metallic springs may be used.

Muscle-grafting may be utilized to overcome the deficiency of paralyzed muscle. The operation consists in blending a neighboring active muscle with the paralyzed muscle. Intervening tissue is removed or drawn aside, the active muscle approximated to the paralyzed muscle and the two sewed together. The adjacent surfaces of the two muscles are simply freshened and united.

Paralysis of the deltoid muscle has been most successfully treated by *transplantation of the trapezius.* An incision is made from the middle of the outer border of the trapezius muscle downward across the shoulder to the lower third of the deltoid muscle. The skin is dissected back, and the trapezius muscle is separated from its attachments to the clavicle, acromion, and outer third of the spine of the scapula. The atrophied deltoid is separated from the clavicle and spine of the scapula. The tendon of the long head of the biceps is then exposed by opening its sheath, and shortened sufficiently to hold the displaced head of the humerus in its socket. The outer half of the capsule of the joint may be shortened also by making a transverse incision and closing it by overlapping. The trapezius should then be attached to the outer aspect of the humerus as low as possible. Usually it will be found that the best that can be done is to sew the free end to the capsule of the shoulder-joint. To carry it any lower is apt to stretch the spinal accessory nerve beyond its physiological, if not its anatomical, endurance. The deltoid should then be brought up and sewed over the trapezius as the arm is held in hyperabduction. The arm should be put up in abduction, and kept in that position for about three weeks.

Instead of suturing the trapezius to the capsule, the deltoid may be forced down to its insertion, and a piece of fascia inserted to connect the trapezius with the tendon of the deltoid. This fascia may best be cut from the upper and outer side of the thigh. A pad of fat should be left attached to it to lie against the capsule of the shoulder-joint. After sewing the fascia graft to the trapezius above and to the tendon of the deltoid below, the deltoid muscle should be sewed over the graft.

The necessity for shortening of the capsule of the joint or the tendon of the long head of the biceps should depend upon the amount of relaxation of the capsule and dropping of the head.

Paralysis of the trapezius muscle, which allows the scapula to fall outward, was treated by O. Rothschild (Zentralb. f. Chir., Nov. 5, 1910) by cutting from the thigh a flap of fascia 20 cm. (8 inches) long and 5 cm. (2 inches) wide and sewing one end to the vertebral border of the scapula above the spine and the other to the latissimus dorsi muscle near the spine. By carrying the flap through a slit in the trapezius and allowing it to run under the latissimus dorsi its adherence to the skin is prevented.

Spasticity of Muscles Treated by Injections of Alcohol.—This paralyzes temporarily the opposing muscles while massage is applied and the nerve of the paralyzed muscle is regenerating. It is a valuable expedient in the paralyses with contraction of the unaffected muscles. The operation is done by isolating the nerve and injecting it by sight with 80 per cent. alcohol. When the nerve supplying the group of muscles which are contracted has been thus paralyzed, treatment can be carried on. Spasticity is caused to disappear by this treatment, but it usually returns in the course of several months. Important motor nerves should not be injected because of the danger of permanent paralysis. The treatment is of value in cross-legged deformity in children due to spasticity of the adductor muscles of the thigh. The

relaxation of the contracted adductors, which is accomplished by the injection, may enable the child to learn to walk before the spasticity returns (See Nerves, page 864).

Rubber elastic prosthesis, to take the place of paralyzed muscles, may be used with good effect in appropriate situations. The rubber may be made fast to the skin by adhesive plaster. This is an expedient of especial value during the recovery from temporary paralysis. If the paralysis is permanent, it is possible to make loops of tendon or connective tissue, covered by skin, and attach the rubber elastic by cords through these loops of living tissue. When this is done, the rubber bands employed should make the least possible pressure (see Cineplastic Operations, Amputations, Vol. III).

Contracture of the psoas parvus muscle, simulating appendicitis, was first described by G. R. White (Annals of Surg., vol. 58, 1913) and later by T. L. MacDonald (Surg., Gyn. and Obst., vol. 19, 1914), and the symptoms cured by division of the tense bands lying behind the peritoneum. The contractured muscle is represented by a band of fascia lying along the inner side of the psoas magnus. The pain, tenderness, and tumor which it causes disappear when the band is divided. The iliac vessels lie to the inner side, and the nerves lie deeply in the muscles, and no important structure is jeopardized by the operation.

The tendon may be divided by an extraperitoneal operation by stripping back the peritoneum as for exposure of the ureter, or by making an incision through the peritoneum. This contracture should be looked for in cases operated upon for appendicitis for in many such cases symptoms persist after removal of the appendix which would have been cured by division of this muscle. Both sides should be examined.

TENDONS

Two points should be borne in mind in dealing with tendons: (1) their blood-supply is meager, hence resistance against infection is low, and healing of wounds is slow; (2) they are contained in synovial sheaths which easily convey infection and to which the tendons easily become adherent.

Repair of Tendons

Wounds of tendons.—The most scrupulous attention to asepsis and the removal of infection are called for in open wounds of tendons (see Wounds, page 213). A tendon which has been divided should be sewed together. This should be done as soon as possible after the accident. Where several tendons are divided, as in the foot or wrist, care should be taken to sew together the divided parts of the same tendon.

Tenorrhaphy is best performed with a small curved intestinal needle and fine slowly absorbable suture material such as chromicized catgut or silk. The skin should be widely cleansed and the wound freed of foreign matter. In most cases it will be found that the proximal side of the tendon has retracted in its sheath and is out of sight. The long tendons of the wrist when divided retract upward from 2 to 4 cm. (¾ to 1½ inches). The sheath should be split downward and upward for a sufficient distance to make it possible to secure the two ends. By relaxing the muscle and squeezing downward over the tendon it can be brought down. When the wound is not an infected one or when it is not feared that infection has been carried into the sheath, the latter need not be split open but simply exposed externally, an opening made in it opposite the retracted tendon-end, the tendon brought out through the opening, sutures applied, and then all

drawn back into the tendon sheath. This is the ideal procedure, as the less wounding of the sheath there is, the less will be the danger of thecal adhesions. In the ordinary slightly infected case, the sheaths between the two ends should be well irrigated with non-irritating solution. The tendon should be grasped laterally near its two ends by means of fine-toothed forceps. A thin slice of the two cut surfaces should be removed to insure aseptic ends, and the sutures applied.

Because of the fibrous structure of tendons, an ordinary suture cannot be used, as it will pull out. Some of the sutures must be introduced in such

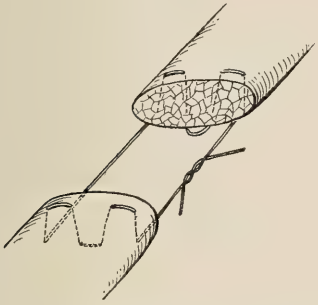


FIG. 611.—SUTURE OF TENDON BY MATTRESS SUTURE.

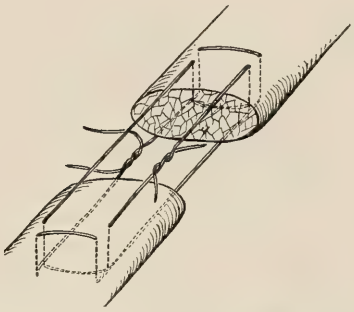


FIG. 612.—DOUBLE MATTRESS FIXATION SUTURE OF TENDON.

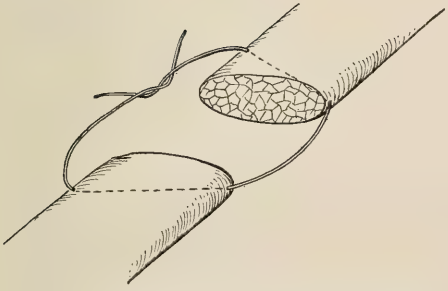


FIG. 613.—SIMPLE SUTURE OF TENDON, WHICH IS PRONE TO PULL OUT AND PROVE INEFFECTIVE.

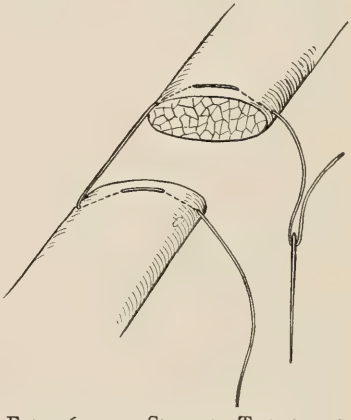


FIG. 614.—SIMPLE TRANSVERSE MATTRESS SUTURE OF TENDON.

a way as to secure lateral tension. A good plan is to introduce two of these loop or mattress sutures and then complete the approximation with ordinary sutures. The sutures may be prevented from pulling out by tying a ligature around the end of the tendon or by putting in some transverse sutures. Before drawing up and tying the sutures the muscle should be relaxed and the ends of the tendon held together with the toothed forceps (Figs. 611, 612, 613, 614, 615, 616, 617, 618, 619 and 620).

Rupture of tendons should be treated the same as other wounds of tendons. The tendon should be exposed by an incision long enough to discover either

end. The frayed out ends should be trimmed and sutured. The sheath should be closed with the least possible irritation, and the overlying soft parts sutured. The results of this operation should be good because the asepsis is in the hands of the surgeon. If the rupture is incomplete it may require no treatment but rest. Tendon which is ruptured or divided in its

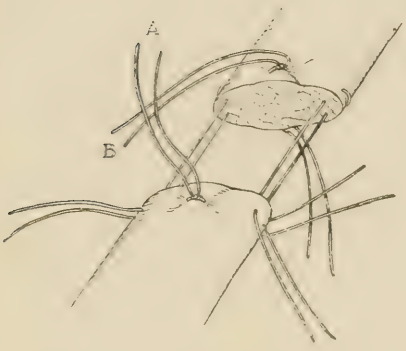


FIG. 615.—KNOTTED SUTURES.

The sutures are first tied to tendon and then tied together. Sutures *A* are tied to sutures *B*.

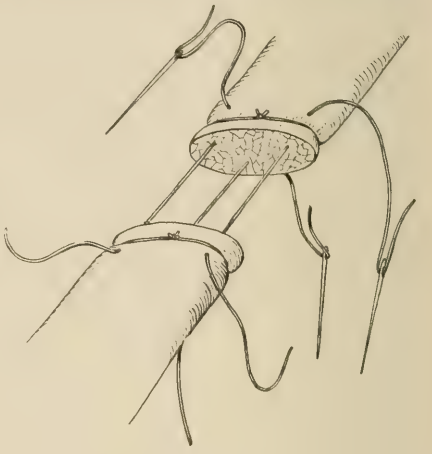


FIG. 616.—LIGATION AND SUTURE OF TENDON.

A mattress suture is passed through the ends of the tendon and tied around it. This serves to prevent the sutures pulling out.

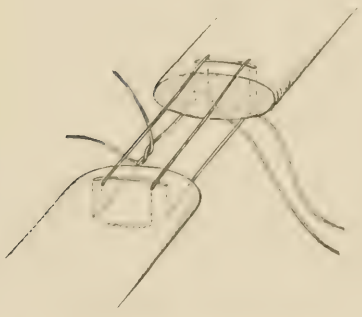


FIG. 617.—SIMPLE INTERRUPTED MATTRESS SUTURES.

Two or more of these sutures may be applied.

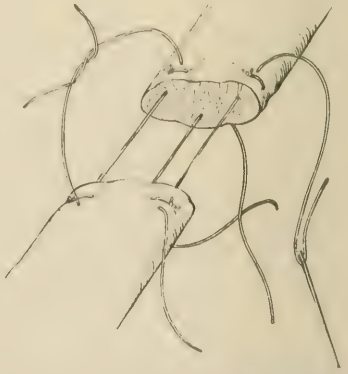


FIG. 618.—METHOD OF PREVENTING TENDON SUTURES PULLING OUT BY FIRST APPLYING A TRANSVERSE SUTURE.

sheath regenerates. The healing which naturally occurs results in lengthening of the tendon; otherwise a perfect functionating healing takes place. If the lengthening of the tendon is not objectionable, no operation is necessary for ruptured tendon. All that is required is that the parts should be immobilized in the position which relaxes the tendon. A month should be given for its healing, and two months should elapse before any considerable strain is imposed upon it.

Tendon Lengthening.—No operation for tendon suture will be successful if there is tension upon the sutures. If when the tendon is brought together and the limb is placed in such position as to give the best relaxation there is

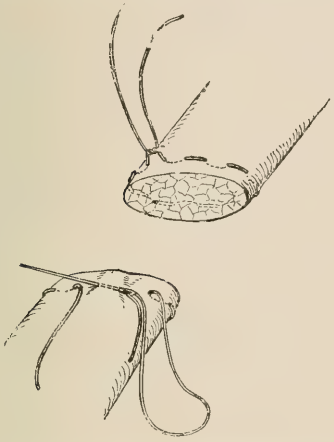


FIG. 619.—PURSE-STRING SUTURE OF TENDON TO PREVENT PULLING OUT OF LONGITUDINAL SUTURES.

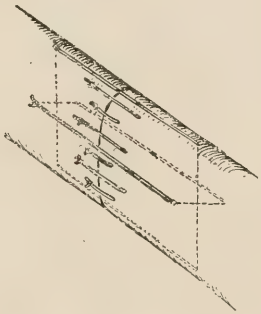


FIG. 620.—TENDON SUTURES WITH RELAXATION SUTURE.

still required some tension to hold the ends in apposition, the suture should not be applied until the tendon has been lengthened by plastic operation (Figs. 621, 622, 623, 624, 625, 626, 627 and 628). Where raw surfaces are

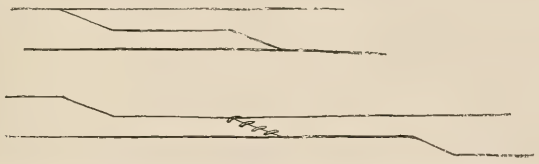


FIG. 621.—TENDON LENGTHENING BY OBLIQUE AND PARALLEL DIVISION.

exposed by splitting large tendons, the raw surface may be buried by whipping it over with a continuous suture (Fig. 629).

If no plastic union is made, the tendon-ends may be connected by a series of parallel sutures which act as a framework upon which new connective

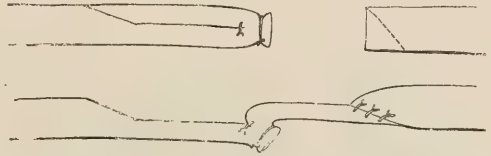


FIG. 622.—TENDON LENGTHENING BY OBLIQUE AND PARALLEL DIVISION, LIGATURE AND SUTURE.

tissue may develop. For this purpose, well-hardened chromicized gut or paraffined silk serves best. Silk is most used. These sutures should be prevented from pulling out by the use of accessory transverse sutures (Fig. 630).

Tendon lengthening is called for not only in traumatic injuries but also in chronic diseases which have resulted in contractures and deformities. The lengthening of tendons for chronic disease may often be accomplished

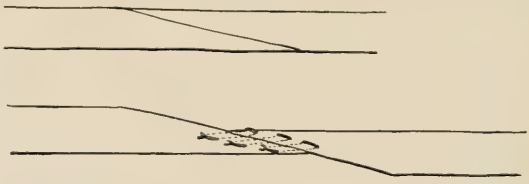


FIG. 623.—TENDON LENGTHENING BY SIMPLE OBLIQUE DIVISION AND SUTURE.

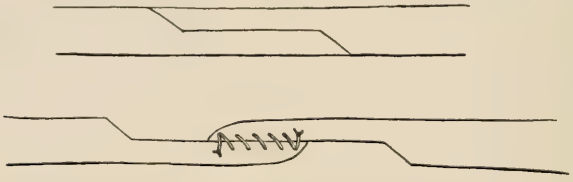


FIG. 624.—TENDON LENGTHENING BY OBLIQUE AND PARALLEL DIVISION AND OVERLAPPING.

FIG. 625.—TENDON LENGTHENING BY OBLIQUE AND PARALLEL DIVISION, LIGATURE AND SUTURE.

FIG. 626.—TENDON LENGTHENING BY TRANSVERSE AND PARALLEL DIVISION LIGATURE. SUTURE, AND SUTURE FRAMEWORK.

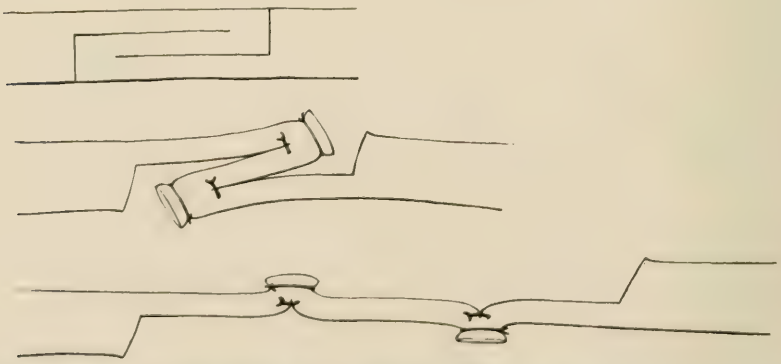


FIG. 627.—TENDON LENGTHENING BY TRANSVERSE AND PARALLEL DIVISION, LIGATURE SUTURE.

by stretching by gymnastics, by apparatus, or by force at one sitting (see Contractures of Joints, page 682). In the chronic diseases, any of the above-described operations may be employed. Tendons may be divided without subsequent suture (see Tenotomy, page 813).

Subcutaneous lengthening of large tendons may be done without subsequent suture in the case of tendons without sheaths. The operations may be done obliquely or transversely. Subcutaneous tenotomy may be done in the case of tendons such as the tendo Achillis, by piercing the skin and tendon at its middle with a tenotome and cutting the tendon transversely halfway through. This operation is repeated at a point 2 or 3 cm. (1 inch) distant

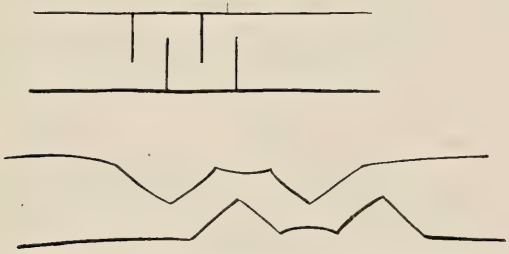


FIG. 628.—TENDON LENGTHENING BY SIMPLE TRANSVERSE INCISIONS.

but the cut made on the opposite side of the tendon. By making strong tension the two cuts are made to separate and the tendon fibers drawn apart by sliding parallel with one another (Fig 631). This operation will give 2 cm (¾ inch) lengthening. If more is needed the incisions may be made further apart or more alternating cuts may be made.

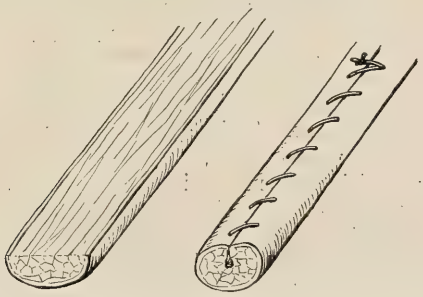


FIG. 629.—LONGITUDINAL INFOLDING OF TENDON TO COVER RAW SURFACE.

Silk and linen tendons were demonstrated by Lange to be effective in situations in which the gap to be filled is greater than can be well treated by tendoplasty or filled by nature. Thoroughly boiled silk is commonly used. The asepticity of the silk is further insured by soaking it in 1 per cent. silver nitrate solution. Four strands may be employed in smaller tendons

FIG. 630.—UNION OF TENDON BY A FRAMEWORK OF SUTURES.

and six or eight strands, or more, in larger tendons. The silk is sewed into the ends of the tendons by the methods used for tendon suture (Fig. 632). This method may be used for periosteal insertion, or the silk may be made fast directly to the bone. The wound should be closed without drainage. The limb in an overcorrected position, to relieve the sutures of strain, is

put up in plaster or splints. Immobilization should be maintained for four to eight weeks. A control apparatus should then be worn for several months. Massage and passive motion should begin about ten weeks after the operation. Lovett regards the operation as valuable in the treatment of dropped ankle of infantile paralysis. The silk serves as a scaffolding around which new connective tissue develops and forms a new tendon. This connective tissue penetrates between the fibers of the silk so that the silk becomes incorporated in the new tendon. Where there is no tendon sheath, but the reconstruction must be made through connective tissue, a foreign body, like silk thread, serves as a guide for the development of tendon-like tissue. Where there is a sheath such a foreign material is not necessary.

FIG. 631.—ELONGATION OF TENDON BY SUBCUTANEOUS TRANSVERSE DIVISION AND STRETCHING.

If an aseptic operation is done the result is generally good. If the least infection is present, the whole operation may be expected to fail, and the thread must be removed. Suppuration and the necessity for removing the silk are common results of this operation.

The introduction of *silk ligaments* may often serve as a *substitute for arthrodesis*. In any joint in which arthrodesis might be indicated for paralysis this method may be used. The ankle and shoulder have been especially benefited. It is especially applicable in the treatment of the paralyzed leg of infantile paralysis with *drop-foot*. In this condition an incision 5 cm. (2 inches) long is made at the lower third of the front of the tibia. The periosteum is divided longitudinally on the inner surface and stripped back for a short distance. Four strands of heavy silk are then woven fast to the periosteum. This silk is best prepared by boiling for half an hour, drying for two days, and then boiling in paraffin for an hour. Another incision is made in the dorsum of the foot over the middle of the tarsal bones, the periosteum of which is reflected, as was done in the tibia. The silk strands are then threaded in the eye of a director which is passed from the upper wound, under the skin and annular ligament, to emerge at the lower wound, where they are sewed into

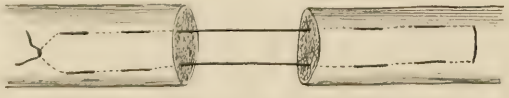


FIG. 632.—SILK AND LINEN TENDONS.

Showing method of inserting sutures. As many of these sutures are inserted as are necessary adequately to fill the gap.

the periosteum of the tarsal bone. The silk strands should be fixed with a degree of tension which holds the foot at a right angle to the leg. The knots should be flattened so that they may not press against the skin. The wounds are then closed, and the ankle immobilized at an angle less than 90 degrees. It should be kept in this position for two months. A brace should be worn in the third month to allow no strain on the silk. Then apparatus may be left off.

Instead of using silk for this purpose, it is my opinion that a strip of fascia lata, taken from the outer side of the thigh, will become the material of choice.

Reconstruction of tendon with fascia is similar to total tendon transplantation. A piece of fascia is cut out lengthwise from the outer side of the thigh or other region and rolled into a strip making a cord about the size of the tendon which it is to replace or represent. This is sutured into the gap and covered with sheath or connective tissue. The operation and results are similar to those of total tendon grafting.

Cases in which tendon has been destroyed by disease or accident lend themselves especially to this operation. This is often presented in the palm of the hand. To continue a tendon from the palm to a phalanx, a strip of

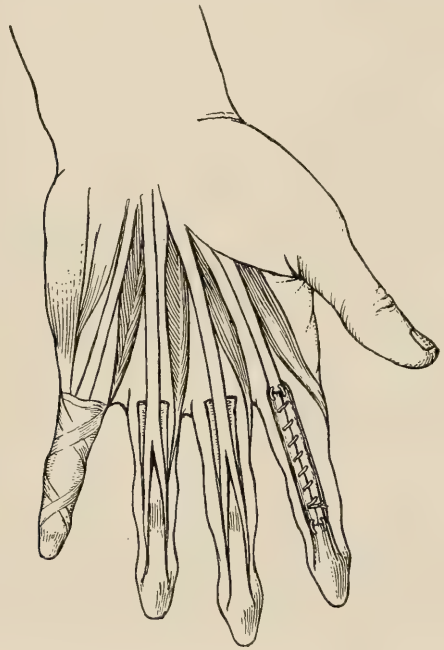


FIG. 633.—RECONSTRUCTION OF TENDON FROM A TUBE OF FASCIA LATA.
The fascia is made into a tube and sutured around the ends of the deficient tendon.

fascia is cut from the fascia lata of the outer side of the thigh. It is advisable to leave a thin layer of fat attached to the fascia. For flexor purposes the fascia may be about 1.25 cm. (1½ inch) wide. It should be attached to the stump of the tendon which should be freshened at its end and inserted into the fascia tube. The fascia should be rolled into a tube, the distal end of which should be sewed to the periosteum or other place of insertion. New tendon may be expected to grow from the stump through this tube (Fig. 633).

Transplanted vein may be used for the same purpose. A vein large enough to receive the upper end of the trimmed-off tendon is placed in the gap, its upper end sutured to the tendon and tendon sheath, and its lower end sutured to the place of insertion. Tendon may be expected to grow into the implanted vein. The vein either becomes adherent to the tendon and becomes changed into tendon structure, or the tendon, growing into it, remains separated from its walls, and the vein functionates as a sheath. This latter result may be facilitated by passing two or four strands of chromicized catgut or kangaroo tendon from the end of the tendon through the

venous tube and attaching them at the place of insertion, and suturing the vein above, not to the tendon, but only to the tendon sheath.

Missing Tendon.—If the proximal end has been torn away or cannot be found the distal end should be attached to a neighboring tendon by some of the methods of tendon lengthening or transplantation. If the distal end is missing the proximal tendon should be brought down and attached to the bone which it should move. This may be done by suturing the tendon to fascia, by lengthening it or by implanting it into another tendon. In the absence of a section of deep tendon, a section of the superficial tendon may be engrafted into the gap.

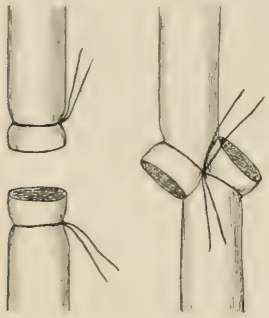


FIG 634.—TENDONS TIED TOGETHER. The ligatures are first passed through the tendons, tied about them, and then they are tied together. This apparently crude method gives ultimately a smooth union.

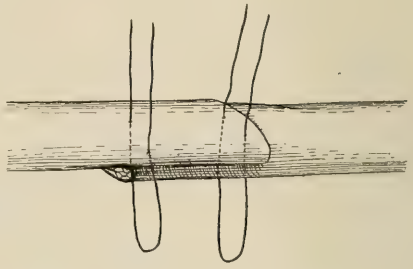


FIG. 635.—OVERLAPPING SUTURE OF TENDON.

To suture a tendon to bone, a flap of periosteum 2 or 3 cm. (¾ to 1½ inches) long should be dissected up, the tendon split in such a way as to broaden its attachment, and sutured to the periosteum. A groove may be chiseled in the bone and the tendon sunk in this groove. A flap of fascia may be used to make the connection.

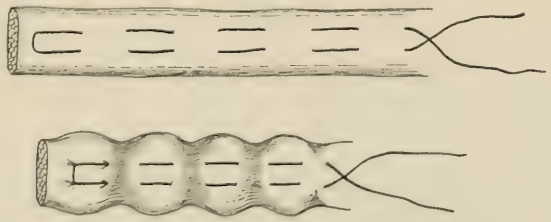


FIG. 636.—SHORTENING TENDON BY PLICATION.

Tendon Shortening.—This operation is called for in partial paralysis in which there is still some power in a relaxed and flabby muscle. It is used to compensate for shortened bones such as follow fracture or disease. It is also required in joint distortions due to unbalance of muscular power, such as is observed in talipes calcaneus, and to change the muscular action upon a joint. Tendon shortening may be accomplished by detaching the tendon from its insertion, cutting off the desired amount and reattaching it. It is also practicable to excise a segment of the tendon. When this is done the excision should be made obliquely in order to give a large surface for union. Tendon-ends may be tied together or overlapped and sewed (Figs. 634 and

635). In some cases it suffices to chisel off the bony insertion, move it along and attach it. Hoffa shortened tendons by running two parallel silk sutures in-and-out lengthwise in the tendon and tying them tight enough to throw the tendon into folds (Fig. 636).

Tendon Transplantation and Tendon Grafting

Total tendon grafting means the resection and transference of a segment of tendon from one part and suturing into a gap for the repair, reconstruction or elongation of another tendon. The implanted tendon may be taken from an amputated part, or a little-used tendon from the same person may be employed. Thus the tendon of the palmaris longus is used to replace an important flexor tendon. A segment from the edge of the tendo Achillis may be used. The new tendon is sutured in the gap and covered with sheath or loose connective tissue. If an aseptic operation has been done the operation is usually successful; if the least infection is present it fails and suppuration demands removal of the grafted tendon. Fascia may be used in place of tendon.

Tendon transplantation usually is used to mean transference of the insertion of a tendon from one place to another. *Tendon grafting* generally implies the implantation of one tendon into another. The operations are used in the same class of cases. Often the two operations are combined. The first operation usually consists in chiseling off from the bone, together with a patch of periosteum, the insertion of a tendon, and implanting it elsewhere by sewing it to a raised-up flap of periosteum. An effective method is to bore a hole in the bone and fix the tendon in it with a suture or a bone peg.

Tendon grafting is done in several ways. The paralyzed tendon may be cut across and its distal end attached to an active muscle; the tendon of an active muscle may be divided and its proximal end attached to a paralyzed tendon or its bony insertion; or a slip from one tendon may be carried across to another.

General Principles and Technic of Tendon Transplantation.—The principles already described under *tenorrhaphy* should be observed. Deformities should be corrected before the operation is done.

The transference of the insertion of tendon into bone is the preferable operation because of the tendency of paralyzed tendon to stretch. This operation cannot always be done because the active tendon is not always long enough. Tendon-to-tendon grafting has the widest application.

The union should be made especially strong as a weak union is apt to separate. A simple end-to-end suture is not as good as one of the methods which give a broader attachment. The implantation method is the most secure. A slit is made in a tendon and the other tendon inserted into the slit or drawn through it (Figs. 637, 638 and 639).

The operation should be done early, as soon as the paralysis has ceased to progress, and before permanent distortion changes have occurred. The operation should be done by the bloodless method.

The muscles should be tested to determine exactly which are paralyzed and which are active. The anatomic problems should be studied from the standpoint of mechanics in order to secure the best myodynamic result.

Muscles having a similar nerve supply are best substituted for one another. This is not an invariable rule. When necessary an extensor muscle may be attached to a flexor tendon, and education will change its function. When muscles which naturally have antagonistic actions are thus combined they should be completely divided, as they cannot be trained to perform two functions.

Fig. 637.

Fig. 638.

Fig. 639.

Fig. 637.—Implantation of Tendon.
One tendon is inserted in slit in other tendon and sutured.

Fig. 638.—Implantation of Tendon.
Tendon is passed through two holes made in recipient tendon and caught by sutures.

Fig. 639.—Implanted Tendon Split and Each Branch Passed Through a Hole in the Receiving Tendon.

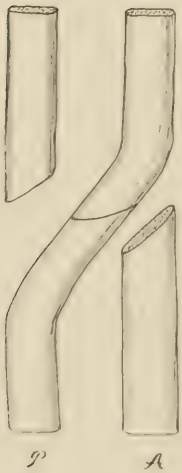


Fig. 640.

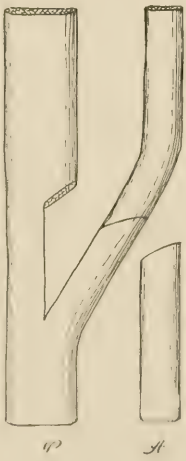


Fig. 641.

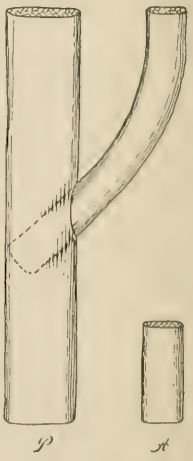


Fig. 642.

Fig. 640.—Showing Principle of Tendon Transplantation.
The tendons *P* and *A* are divided and the paralyzed tendon sewed to the active tendon.

Fig. 641.—Tendon Transplantation.
Active tendon (*A*) is divided and sutured to slip split from paralyzed tendon (*P*).

Fig. 642.—Tendon Transplantation.
Active tendon (*A*) sutured in incision in paralyzed tendon (*P*). Thus tendon of extensor hallucis (*A*) is transplanted into paralyzed tibialis anticus (*P*).

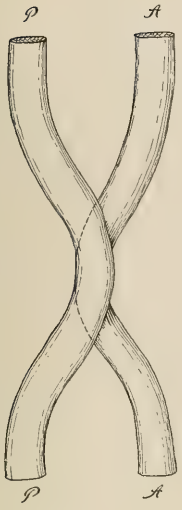


FIG. 643.

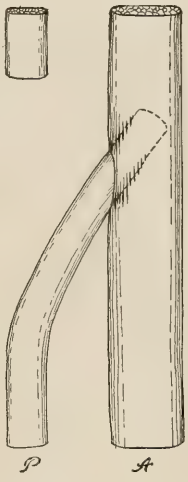


FIG. 644.

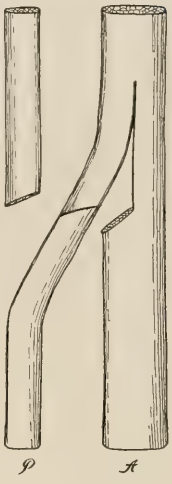


FIG. 645.

FIG. 643.—TENDON TRANSPLANTATION.
Active tendon (*A*) sutured laterally to paralyzed tendon (*P*).

FIG. 644.—TENDON TRANSPLANTATION.
Paralyzed tendon (*P*) divided and distal end sewed to active tendon (*A*).

FIG. 645.—TENDON TRANSPLANTATION.
A slip is cut from the active tendon (*A*) and sutured to the divided paralyzed tendon (*P*).

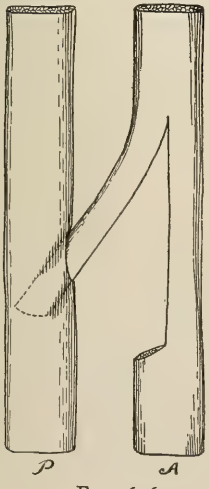


FIG. 646.

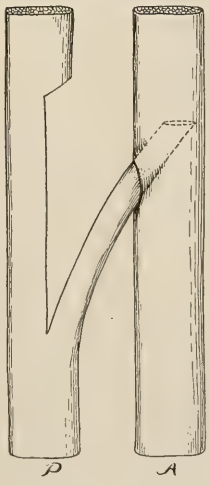


FIG. 647.

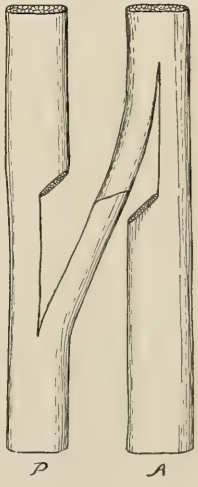


FIG. 648

FIG. 646.—TENDON TRANSPLANTATION.
A slip is cut from the active tendon (*A*) and inserted into the paralyzed tendon (*P*). Showing part of tendon of extensor hallucis (*A*) inserted into paralyzed tibialis anticus (*P*).

FIG. 647.—TENDON TRANSPLANTATION.
A slip is cut from the paralyzed tendon (*P*) and inserted into the active tendon (*A*).

FIG. 648.—TENDON TRANSPLANTATION.
A slip is cut from each tendon and united between. *A*, Active; *P*, paralyzed.

The degree of tension is important. There should neither be too much tension nor too much relaxation. The strictest aseptic care is essential. Infection defeats the object of the operation.

It is desirable that the scar in the superficial tissues shall not directly overlay the line of tendon suture because of the tendency to form adhesions. In exposing the tendons flaps should be turned back. If tendons remote from one another are to be used, it is often better to make two separate wounds of approach, and then draw one tendon through the sheath of the other. When necessary a tendon may be drawn through an artificial opening made in the subcutaneous tissues; in the course of time it makes a canal for itself in such tissues, and its function is not interfered with. The principles of the technic are shown in Figs. 640, 641, 642, 643, 644, 645, 646, 647, 648 and 648*A*). The question as to whether the sound tendon shall be divided must depend upon the importance of the function which it naturally performs. Usually it is best not to sacrifice it. The operation which is most advantageous is that in which the paralyzed tendon is divided, and its distal stump fastened to an adjacent active muscle, without division of the latter.

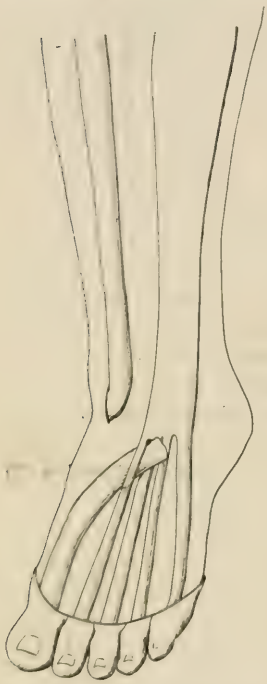


FIG. 648*A*.—TENDON TRANSPLANTATION.

Active extensor hallucis transplanted to inner side of foot to take the place of paralyzed tibialis anticus. Distal end of extensor hallucis tendon attached to extensor digitorum.

After-treatment.—In closing the wound, the tendon sheaths should be sutured with fine catgut. A special effort should be made to lay smooth synovial tissue over the lines of tendon suture or raw tendon surfaces. The overlying structures should be carefully approximated. All the while, the parts should be held in overcorrection to relieve strain on the sutured tendon. A splint should be used to secure immobilization not only of the joint but also of the muscles involved in the operation. From four to six weeks should be given for the tendons to become strongly united; but gentle massage should be used after the tenth day, and the joint passively and carefully moved from its position of overcorrection to the normal position, but not beyond. After the sixth week the muscle may be used voluntarily. An apparatus should be applied to prevent the joint moving beyond the normal position but which permits it to move toward overcorrection. Such an apparatus should be worn from two to six months. Careful exercise of the muscle should be practised. It is the painstaking attention to the after-treatment of these cases that must be looked to to complete the success.

Indications and Results.—The substitution of an active muscle to perform the function of a paralyzed one finds its chief application in infantile paralysis, although mechanical damage, local infective paralysis, or distortion from weakness of a muscle also require it. Paralytic club-foot and paralyses affecting the knee, shoulder and elbow are amenable to these operations. The operation is often combined with arthrodesis in such cases as paralysis of most of the leg and thigh muscles. Here, by producing an artificial ankylosis at the ankle and performing tendon transplantation or tendon grafting at the knee, a limb which had been flail-like and useless may be converted into a useful member.

These operations should be done with the least possible traumatism to the tissues. The direction of traction should be such as will enable the muscle to act effectively. For this reason the transplanted working tendon should preferably be inserted at the same place of insertion as the paralyzed tendon. The tendon should lie in such relations that it may glide freely.

Results are good, if an aseptic operation has been done, and careful after-treatment pursued, in cases of not too long-standing paralysis. It is possible to benefit most cases to some degree. The best successes in infantile paralyses have been secured in such operations as making the tibialis anticus perform the function of the extensor longus digitorum. The peronei and even the tibialis posticus have been carried around the malleoli to these anterior tendons. A talipes varus position has been remedied by attaching the tibialis anticus to the outer border of the foot.

In paralysis of the tibialis anticus, good results may be secured by connecting to it the tendon of the extensor proprius hallucis or by inserting the extensor into the periosteum at the place of insertion of the paralyzed muscle. In paralysis of the gastrocnemius, the peronei or tibialis is used. If flexors of the leg are active, in paralysis of the extensor femoris, the hamstring muscles may be inserted into the extensor tendon. The trapezius may take the place of the deltoid. The pronator radii teres has been converted into a supinator by passing it through the interosseous membrane and reinserting it on the outer side of the radius. The flexor carpi ulnaris has been made an extensor by inserting it into the extensor carpi ulnaris. The radial flexor has been cut and inserted into the radial extensor. The pronator radii teres has been detached at its origin and transferred to the external condyle of the humerus. In connection with this the radial and ulnar flexors of the wrist are inserted into the extensor communis digitorum, to improve supination and extension.

Special Transplantations.—*Transplantation of the extensor proprius hallucis for the tibialis anticus* is done to remedy slight paralytic valgus. The insertion of the tibialis anticus is exposed by an incision 4 cm. (1½ inches) long placed transversely on the inner side of the foot, with a downward convexity. The tibialis tendon is split longitudinally for a distance of 4 cm. at its insertion, the periosteum is incised in the same direction and separated from the bone on either side. A groove is made in the internal cuneiform in this opening. The extensor proprius is exposed by an incision parallel with its tendon, beginning 3 cm. (1 inch) above the tip of the inner malleolus and passing downward to the middle of the first metatarsal bone.

About 2 cm. (¾ inch) above the malleolus the two tendons are separated by a thin septum. At this level a small opening should be made in the sheath of the tibialis. The extensor hallucis is then liberated by splitting its sheath its entire length and the tendon divided about at the middle of the metatarsal bone. The end is grasped with a clamp and the mesotenon divided as the tendon is lifted up. It is freed up to the muscle. A double looped suture of chromic catgut is passed through the end of the tendon (see Tendon Suture, page 796), and the tendon drawn through the sheath of the tibialis by means of a probe. The sheath is ample to accommodate the two tendons.

The tendon should be sutured in its bed in the split tibialis tendon. The relaxation of general anesthesia allows the tendon to be fixed with the foot in the normal position of about right-angle flexion. In suturing the tendon, the sutures should be passed with a strong cervix needle through cartilage, bone, ligament and fascia. A firm fixation should be made, and then the split tibialis tendon sewed over it.

The distal stump of the extensor tendon should be attached to the adjacent tendon of the extensor digitorum longus, and the wound closed.

Transplantation of the tibialis anticus for the peroneus tertius is done to correct paralytic adduction of the foot. This operation aims to convert the tibialis into an abductor muscle. The operation is useful not only in paralytic or spastic inversion of the foot but in some cases of congenital talipes varus. An incision 4 cm. (1½ inches) long is made on the outer side of the foot over the insertion of the peroneus tertius. The incision should be curved with its convexity forward and should cross the fifth metatarsal bone at the junction of its posterior and middle thirds. The flap of skin and superficial fascia should be turned back.

An incision is then made over the tibialis tendon, beginning 3 or 5 cm. (1 or 2 inches) above the level of the malleolus, and passing downward to

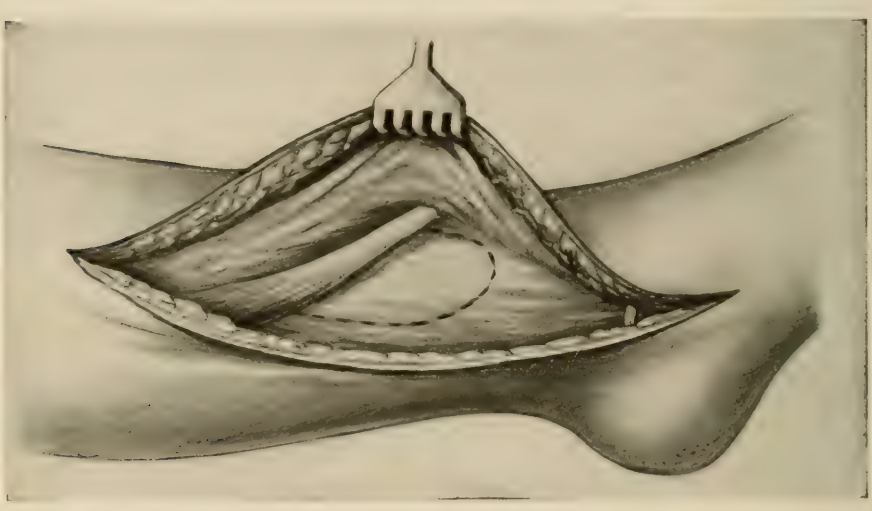


FIG. 649.—TRANSPLANTATION OF PERONEUS LONGUS FOR TIBIALIS ANTICUS.

The tendon of the peroneus longus has been divided, lifted from its bed, carried obliquely across and sutured to the tibialis anticus. A flap of fascia has been marked out to cover the tendon.

the insertion of the tendon. The tendon sheath is incised throughout its entire length, and the tendon divided close to the bone, preserving as much of its length as possible. A strong chromic catgut looped suture is then passed through its end. The suture is threaded through the eye of a probe. The tendon is then cut free from its mesotendon, the probe is passed through the septum and into the sheath of the peroneus tertius which lies adjacent to the extensor tendons. The probe should pass anterior to the latter, and emerge at the wound exposing the peroneus tendon. The tibialis tendon is drawn down through the peroneus sheath and made fast to the bone by the method described above for the extensor proprius.

This operation is indicated only when a strong pull is desired. In slight degrees of varus, the extensor proprius hallucis should be employed.

Transplantation of the peroneus longus for the tibialis anticus is done when anticus paralysis gives rise to paralytic or spastic talipes valgus. The operation requires especial care because the two tendons do not lie close together but are separated by the dense fascia which divides the external from the anterior group of muscles.

An incision is made over the insertion of the tibialis anticus, the tendon is split, and the cuneiform bone is grooved as is described above. A second

incision is made 3 cm. (1 inch) long at the upper limit of the sheath of the tendon. The middle of this incision is 3 to 5 cm. (1 to 2 inches) above the level of the malleolus. The sheath is opened, and a probe, carrying a suture, is passed down within the sheath to the lower wound.

A third incision is made over the tendon of the peroneus longus from the middle of the leg, downward behind and below the outer malleolus to the cuboid bone. The upper and lower ends of the incision curve forward. The flap of skin is dissected forward in the leg, and the fascia covering the peronei and anterior muscles is exposed. As much subcutaneous fat as possible should be left attached to the deep fascia which covers the muscles. The peroneal tendon is then freed from its sheath which is opened throughout

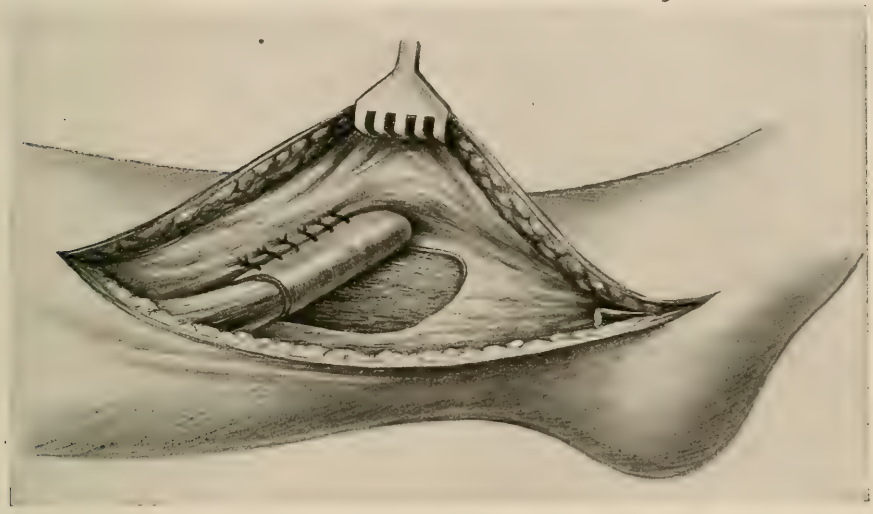


FIG. 650.—PERONEUS LONGUS TRANSPLANTED TO TIBIALIS ANTICUS.
Flap of fascia covering peroneus longus tendon has been turned up and sewed in place.

its whole length and detached from its insertion. It is placed external to the fascia, and drawn through the sheath of the tibialis by a double-looped suture, an opening having been made in the fascia and sheath. A flap of fascia is then cut with its convexity directed downward and backward just below and behind the transplanted peroneus tendon (Fig. 649). This flap is dissected up and, with its fatty side next to the tendon, is wrapped about it and sewed. This forms a sheath for the tendon in that part not covered by the sheath of the tibialis (Fig. 650).

The end of the peroneal tendon is fixed to the internal cuneiform bone in the groove in the split tibialis insertion, and the wound closed.

This operation may be combined with transplantation of the extensor proprius hallucis to the same point, if more power is desired than can be supplied by either muscle alone. When this is done the extensor hallucis is transplanted with its sheath.

The above-described operations indicate the manner of procedure for the substitution of an active muscle for a paralyzed one. This principle may be applied anywhere in the body. Especially in the paralyses of the muscles of the leg which give rise to malpositions of the foot are these operations most useful.

In *paralytic talipes valgus*, not only the above operations are applicable,

but other muscles may be used. The extensor longus digitorum and peroneus tertius may be transplanted into the inner border of the foot. The flexor longus digitorum may be transferred through the sheath of the tibialis posticus and inserted into the scaphoid bone.

In *paralytic talipes varus*, not only may the tibialis anticus be transplanted through the sheath of the extensor longus digitorum and peroneus tertius into the base of the fifth metatarsal bone, but any other available muscle may be used to replace the lost function of the abductors. The extensor proprius hallucis or the flexor longus hallucis may be used for the same purpose.

In *paralytic talipes equinus*, the peroneus longus may be transplanted through the sheath of the tibialis anticus to the internal cuneiform bone; or the peroneus brevis may be transplanted to the base of the fourth metatarsal bone; or both operations may be done.

In *paralytic talipes calcaneus*, the flexor longus hallucis or the peroneus longus may be transplanted to the tuberosity of the os calcis; or both muscles may be transplanted.

(For further discussion of these operations, see Club-foot, Vol. III.)

In *paralysis of the extensors of the hand*, the flexor carpi radialis may be transplanted through the sheath of the extensor carpi radialis longior to the base of the second metacarpal, and the flexor carpi ulnaris may be transplanted into the tendon of the extensor carpi radialis. Both muscles should be transplanted.

In *paralysis or destruction of the extensor tendon of a single finger*, the index-finger tendon of the extensor communis digitorum may be transplanted.

In *paralysis or destruction of the flexor tendon of a single finger*, the adjacent tendon of the flexor sublimis digitorum may be transplanted.

In *paralysis of the biceps of the arm*, the long head of the triceps may be transplanted into the insertion of the biceps.

In *paralysis of the quadriceps extensor* of the thigh, the biceps or sartorius may be transplanted into the patella, or the gracilis or semitendinosus may be transplanted into the patellar fascia. If the biceps is transplanted into the patella, the sartorius gracilis or semitendinosus also should be transplanted to prevent outward displacement of the patella.

(For further description of these methods, see Biesalski u. Mayer: "Die physiologische Sehnenverpflanzung," Springer, Berlin, 1914.)

Luxation of Tendons

Luxations of the Tendon of the Quadriceps Femoris Muscle.—This is a very commonly dislocated tendon. The tendon carries with it the patella, which may or may not be rotated. For convenience the patella serves as a guide in describing these luxations which have heretofore been discussed in surgery as "dislocations of the patella" (see page 648).

Luxations of Other Tendons.—The tendons of the peronei muscles serve as types of tendons which are prone to displacement. The tendon slips forward over the outer malleolus. It can usually be pressed back into place in recent cases. To secure its retention and the healing of the torn sheath, the tendon must be held back with a pad strapped in front of it. The parts should be kept at rest. The swelling should be treated by elevation and bandages.

Old or neglected cases of displaced tendon are best treated by operation. The tendon should be exposed by an incision which turns back a flap so that the skin incision shall not overlay the sheath incision. If the natural sheath

of the tendon has become obliterated by connective tissue, it should be dissected free, the tendon liberated and replaced in its normal bed. A barrier should be sewed in place to prevent further luxation. This should be from the annular ligaments or adjacent fascia. Sometimes it may best be made by chiseling up a barrier of bone and periosteum. Expedients for the prevention of adhesions are useful. The parts should be immobilized in plaster-of-Paris for from four to six weeks.

Tenotomy

Division of tendons is called for to relieve deformities caused by contractured muscles in infantile paralysis, by cicatricial contractions, for spastic paralyses and other deforming muscular contractures. Tenotomy may be open or subcutaneous.

Open tenotomy is done by exposing the tendon by a suitable incision, preferably one running parallel to it, and dividing it under the guidance of

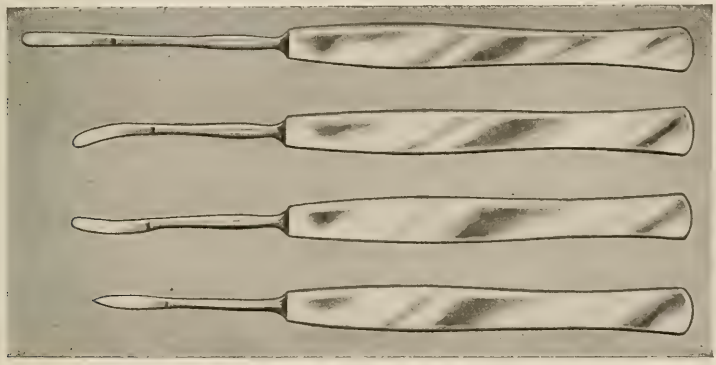


Fig. 651.—Tenotomes.

sight. The open method is to be preferred in cases in which other structures besides the tendons require attention, and in cases in which the tendon is in close relation to important structures, the wounding of which would be hazardous. In the first instance, tenotomy is often required in cases in which the tendon is but one of the contractured structures, and fascia, ligaments, and connective tissue require division. In the second instance, division of the sternal insertion of the sternomastoid should be done by the aid of vision because of the closeness of the great vessels of the neck. After performing open tenotomy, and observing that the operation has accomplished the required correction, the skin wound should be sutured.

Subcutaneous tenotomy is performed with a small narrow-bladed knife, called tenotome (Fig. 651). The knife should have a short cutting edge, not longer than 1.25 cm. (½ inch) and a rounded shank. Is should also have the handle so marked that the surgeon may know which way the cutting edge is directed. This makes a small skin puncture, not a skin incision. The tendon to be divided is made tense. The sharp-pointed tenotome is made to pierce the skin at the side of the tendon. The tendon is then relaxed and the tenotome is passed flatwise between the skin and the tendon until the point reaches the other edge of the latter. The instrument is then rotated with its back toward the skin, the tendon is put on the stretch strongly by an assistant and the knife is made to divide its fibers. This is done by short strokes. Care should be taken that only the tendon is cut. The surgeon's

finger upon the skin feels a gap develop in the tendon. As the last fibers are cut, it parts with a snap. The tension should be continued while the surgeon feels for undivided fibers which sometimes exist. When found they should be cut. A notch is felt between the divided ends. The tenotome is carefully withdrawn so as not to enlarge the wound, a pad of gauze is firmly bandaged over the puncture and the part immobilized in a splint. Should hemorrhage occur from the accidental injury of a large vessel it must be exposed by open incision and the bleeding controlled. Slight bleeding from small vessels requires no special attention.

Healing.—It is usually desired that the tendon should heal and again functionate. The operation is, therefore, essentially an operation of tendon lengthening. A tendon which it is desired should grow together, is best not divided in a tendon sheath, but preferably where it lies in connective tissue. The gap made by the cut in such a tendon will fill in with scar tissue which will ultimately become converted into tendon, and the function will be fully restored. If a tendon is divided where it has a sheath, the ends retract, and not only they but the intervening scar becomes fixed to the sheath, and the muscle then operates upon the sheath and not upon the natural insertion of the tendon. For this reason tendons surrounded by a sheath should not be treated by tenotomy alone, but when such an operation is called for, tendon lengthening should be practised (see page 799). After tenotomy, immobilization in plaster-of-Paris or other splint is required for from four to six weeks; after which, massage is of service.

Tenotomy of the Tendo Achilles.—This is the most commonly practised of the tenotomies and will be described as illustrative. It is done for talipes equinus, flatfoot, dislocations and fractures, and contracture deformities, due to wounds and inflammations.

There are four methods of doing the operation: (1) by inserting the tenotome on the inner side of the tendon, (2) on the outer side of the tendon, (3) by cutting the tendon from behind forward and (4) by cutting from the front backward. There is little choice of methods in skilled hands; in unskilled hands, all are fraught with objections.

By passing the tenotome between the skin and the tendon first, the skin is less apt to be cut and the surgeon can be sure that he cuts all the fibers of resisting tendon and fascia. There is somewhat more danger to the vessels. By passing the tenotome at first in front of the tendon, the vessels are left behind it as it cuts through the tendon. It is preferable to introduce the knife at the inner side of the tendon because the location of the shank is under better control than that of the point, and injury of the vessels is most apt to be inflicted with the point. If a large vessel is cut, it should be exposed and the hemorrhage controlled. This is desirable not only because of the checking of the hemorrhage and the avoidance of traumatic aneurism, but also to give an opportunity to see if the nerve has been cut and to suture it if it has. From four to six weeks of immobilization are called for.

Tenotomy of other tendons is practised in the same manner as that of the tendo Achillis. Where the tendon lies dangerously close to the vessels, it is an additional precaution to use a blunt-pointed tenotome after making the skin puncture.

The **tendon of the tibialis anticus** must often be cut for talipes varus. The operation is best done between the annular ligament and the insertion of the tendon. The division should be made near the insertion in order to avoid the other dorsal tendons and vessels, and is most easily done by cutting toward the skin.

The tendon of the **tibialis posticus** is usually divided 2.5 to 5 cm. (1 to 2

inches) above the tip of the inner malleolus. The open operation is best. This should be done through a small vertical incision which need not be more than 2 cm. (¾ inch) long. The long saphenous vein and internal saphenous nerve are the superficial structures to be avoided. The tendon is easily separated from the deep structures, brought out with a blunt hook, and divided. The tendon of the **flexor hallucis longus** may be divided through the same wound.

The tendons of the **peronei** muscles sometimes require division in talipes valgus. Subcutaneous tenotomy is done 2.5 or 5 cm. (1 or 2 inches) above the tip of the outer malleolus, by cutting toward the skin.

The **hamstring tendons** require division in some cases of fracture near the knee in which their contraction prevents reposition or retention of fragments. In inflammatory diseases, intractable flexures, and following arthrectomy, division of these tendons may be necessary. Any or all of the tendons may require division.

The tendon of the **biceps femoris** lies in such close relation to the external popliteal nerve that its tenotomy is best done by the open method. The tendon of this muscle is so large that when the function of the knee is to be restored an operation for tendon lengthening is best (see page 799). The operation is done through an incision about 5 cm. (2 inches) long on the outer side of the tendon. The iliotibial band may also require division. The external popliteal nerve lies on the inner side of the tendon.

Division of the tendons of the **semimembranosus and semitendinosus** is done the same as for the biceps. The operation is more easily accomplished by the open method, although there are no important structures which may be damaged. Both are usually divided at the same operation. When the subcutaneous operation is done the tendons are cut toward the skin. The tendons of the **sartorius** and **gracilis** are internal to the hamstring tendons.

The **sternomastoid** muscle requires division at its tendinous insertion for torticollis and for giving exposure for operations in the neck. The open operation should be done. There are two distinct insertions, the clavicular and the sternal. The internal jugular vein lies behind the muscle. It joins the subclavian to form the innominate vein just posterior and below the insertion of the tendons. The external jugular vein passes down behind the posterior border of the muscle. The anterior jugular vein lies at its anterior border and passes behind the muscle. Division of the deep cervical fascia lying behind the muscle is often required to make the operation effective. The head should be thrown back slightly by means of a thin pillow under the shoulders. The patient's breathing should not be embarrassed, in order that the great veins shall not be distended. Where the two insertions are quite distinct, a short vertical incision may be made over each one. In children the insertions are so close together that the operation can be done through a single incision. This may be made obliquely from the outer border of the muscle downward and inward and ending just above the sternal notch. The muscle should be exposed by dissecting away the overlying tissues. The muscle is divided transversely by repeated touches of the knife. When the tendon has been completely divided it gaps, and there is little danger of wounding the veins because they come into view before being cut.

The head should be flexed laterally to put the muscle on the stretch, while the surgeon places a finger in the wound to detect any resisting bands of fascia. These should be carefully divided. In dividing resisting bands the surgeon may be led to the sheath of the great vessels, and in long-standing cases a considerable dissection may be required before the operation is com-

pleted. Bleeding should be well controlled. The desired position of the head having been secured, the wound should be closed, a compressing dressing applied and the head immobilized in such a position as to put the muscle on the stretch: that is, with the chin rotated toward the affected side and the head laterally flexed away from it (see Torticollis, Vol. II).

Old Wounds of Tendons

Wounds of tendons which have healed and left adhesions which seriously impair function are amenable to treatment. In the case of a wound which has not divided the tendon but which has left it adherent to its sheath' the scar tissue should be excised, the tendon liberated from adhesions and the wound carefully closed. If the tendon has been divided and the ends are involved in cicatrix as commonly occurs, the scar tissue should be excised and the ends liberated. If they cannot be united one of the methods of tendon lengthening should be employed (see page 799). The difficulties in these cases are very great. The raw surfaces of the tendon tend to become adherent to the surrounding wound. Success can be secured by producing the least possible traumatic reaction. After union of the tendon has taken place, massage and careful use may be expected to free it from its adhesions, or a subsequent operation may be done to accomplish this end. In these particular cases measures for preventing adhesions may be used.

The Prevention of Adhesions

The prevention of adhesions between serous surfaces which should glide over one another is one of the delicate problems of surgery. It involves the peritoneum and joints as well as tendons. The same principles are involved in all. When such serous surfaces become denuded of their endothelial cells, or become covered with inflammatory cells, they adhere. The adhesions become especially firm if the natural endothelium is absent from both apposed surfaces. The object to be attained is to keep the surfaces apart until endothelial cells have grown over each of them or until they can be covered by plastic operation. Many expedients have been resorted to—all with varying success.

The sheath of a neighboring tendon may be dissected free and turned over to form a covering for the sutured tendon.

The intervening septum between the tendons may be removed, and the damaged tendon allowed to lie directly in contact with one or more other tendons. Synovial membrane may be turned in from some neighboring joint or bursa.

The damaged tendon may be wrapped about with some tissue capable of organization, such as vein wall, fascia, fascia and adipose tissue; or with some slowly absorbable material, such as cargile membrane, egg membrane, dried peritoneum, decalcified bone-tubes, intestinal tubing, catgut, etc. In using these materials, if there is a sheath, sufficient thickness should be placed between the tendon and its sheath, the absorption of which will not be completed until all raw surfaces shall have had time to become covered with endothelium. The use of substances which are capable of organization gives the best results. Omentum, bursal sac, hydrocele sac or fascia lata with a thin layer of fat adherent are the materials which lend themselves best for the patching or reconstruction of tendon sheaths to avoid adhesions.

The filling of the tendon sheath with some slowly absorbable lubricant material such as cocoa butter or olive oil has been of service in some cases (see Prevention of Adhesions in Joints, page 756).

Tenosynovitis

Tenosynovitis or thecitis involves the synovial membrane of either or both the tendon and the sheath. It occurs most commonly in the regions of the wrist and ankle.

Traumatic tenosynovitis should be treated by removal of the cause and by rest. Rest is best secured by the use of a simple splint to prevent motion of the joints over which the inflamed tendon and muscle play. If there is effusion of fluid in the sheath, compression by means of bandage or adhesive strapping will hasten its absorption. Healing should take place within ten days. By the end of that time, if there is still pain, tenderness and crepitation, some local hyperemic treatment should be added. Hot applications, wet or dry, or the use of artificial congestion are called for. After the subsidence of inflammation, any remaining stiffness or adhesions should be treated by massage and painless passive motion.

Toxemic tenosynovitis, once called "rheumatic," should be treated by discovering and eliminating the autotoxic cause. Locally, an immobilizing splint, and hyperemia by hot applications or Bier's method should be applied.

Infective tenosynovitis results usually from wounds penetrating the tendon sheath or from adjacent infections extending through it. The resistance of tendons against infection is very poor. These structures are prone to spread an infection once established; rarely they slough and come away. Two features of treatment are imperative: free drainage of the tendon sheath to prevent tension and the pressing onward of infective noxa, and immobilization of the tendon to promote adhesions and to prevent further distribution of infection. Drainage is best secured by means of small sized rubber tubing. In addition to these, artificial hyperemia by suction or passive congestion is of great value. The disease occurring in isolated tendon sheaths is easily managed by these principles. Occurring in the hand or foot, where the tendons are close together and the sheaths communicate, and where many small joints between the bones exist, all in close relations, the disease is more serious, and unless dealt with promptly and effectively may lead to extensive cellulitis of the whole limb, septicemia and death. As soon as the infection is recognized incision should be made into each infected tendon sheath, and tubular drainage inserted. Sterilization with chlorin solutions is the most useful antiseptic treatment (see Infections of Tendon Sheaths and Infective Processes in the Hand, Vol. III).

Gonorrheal tenosynovitis should receive the same general treatment as gonorrheal arthritis. Immobilization and the induction of artificial congestion are to be first applied. Gonorrheal infection of the genito-urinary tract should be looked for, and treated if found. If tension from exudate produces much pain the distended tissues should be incised. The use of antigonococcic serum or vaccine is of service. Massage and motion of the tendon must be begun as soon as the inflammation has gone, in order to prevent adhesions.

Syphilitic tenosynovitis requires specific antisyphilitic treatment. Rest of the tendon should be secured during treatment.

Tuberculous tenosynovitis manifests itself in three main forms: the granulation form, the exudative form, and the combination of the two. Its treatment should follow the same lines as laid down for tuberculous arthritis. Hygienic treatment of the patient, antitubercular treatment, rest of the parts, and the induction of artificial hyperemia should be employed in all cases. Compared with these, the operative treatment is of minor importance (see Tuberculosis, page 276).

Operation is indicated when the above measures fail. The granulation or fungous tissue should be exposed by incision and dissected out. This

often means removal of the swollen tendon sheath for a considerable length of its course. If the tissue is broken down, it may be curetted away. When all of the swollen tissue has been dissected out, the wound should be treated with iodoform or other antituberculous medication, drainage provided, the wound sewed, and the parts put up with dressing and a splint. This operation is best done under artificial ischemia.

In some cases with mixed infection, or in which removal of all of the disease has not been accomplished, the wound may be packed with gauze and left open.

In exudative tenosynovitis, the fluid should be evacuated through a small incision or canula puncture, the sheath washed out with salt solution, injected with iodoform emulsion or other medicament, and dressing and splint applied. If rice-bodies or plastic exudate are present, a free opening must be made for their removal. The curet may be used. Excision of all of the diseased tissue is a quick and effective method of treatment in all cases.

Ganglion

Ganglia are connective-tissue tumors developing in the synovial structures about tendons and joints, and undergoing central colloid degeneration which often comes to communicate with the synovial cavity. They are found most commonly on the dorsum of the wrist, although they may occur in the palm, dorsum of the foot, knee-joint, and elsewhere. If they cause no pain, discomfort or weakness, they need no treatment. Often they disappear without treatment. When they give rise to any of these symptoms they should be removed. Excision under local anesthesia is the most satisfactory treatment. The operation should be complete because if some of the tissue is left, recurrence is possible. The operation will usually open the tendon sheath. This opening should be sutured, the wound closed, and the parts immobilized with a splint for ten days.

The old-fashioned method of treatment was to lay the wrist on a firm support and hit the tumor a blow with a book. This ruptured the wall and dissipated the colloid contents into the tissues. To the credit of this crude method, it may be said that it was effective in a majority of cases in which it was used. Surgeons are implored not to employ so inaccurate a method.

Fascia

The surgery of fascia is discussed in connection with the various lesions, in which diseases must be dealt with, such as contractures of joints, ankylosis, hernias; and in surgical operations in which fascia is used, such as arthroplasty, making tubes for the repair of nerves and tendons, covering and strengthening sutured blood-vessels, substituting for dura mater, making suture material, and providing a substitute for paralyzed or destroyed muscle.

Fascia may be kept sterile in cold storage for many days, and then be used for the above purposes. For bridging the gap between the functionating part of a muscle and a point of attachment, fascia is capable of being put to a large variety of uses. For taking the place of the removed patella or strengthening the quadriceps extensor tendon, fascia is most serviceable. A piece of fascia, cut to the right size and placed around under the edge of a skull defect, heals and substitutes effectively for dura mater. For strengthening weak places in the abdomen, transplanted fascia has much to recommend it over silver filigree. All of these uses of fascia are described under their respective heads.

BURSÆ

In the surgery of bursæ it should be remembered that these structures are not constant and that certain bursæ communicate with joints and tendon sheaths.

Contusions of bursæ cause a bursitis which subsides with rest. Hemorrhage into the sac may distend it. For this, pressure is required until the bleeding is controlled, and then incision and evacuation of the blood.

Wounds of bursæ should be treated the same as wounds of joints. There is but little tension, and fine catgut may be used. The needle should pass down to the synovial membrane, but not through it. A large wet dressing should be applied and the parts immobilized for ten days with a splint. Infection calls for drainage.

Infective bursitis is treated the same as tenosynovitis. If the infection is mild, it may resolve under the use of hot applications. If the infection is very acute or if a mild infection goes on to suppuration, free incision is essential. The sac should be washed out, drainage provided and a large wet dressing applied. In some acute cases the lining of the sac will be found necrotic. Such cases should be treated by curetting or dissecting out the necrosed sac and packing the wound with antiseptic gauze. When the infection seems very virulent or when the sac is not removed, it should be swabbed out with phenol followed by alcohol.

Acute noninfective bursitis occurs as the result of traumatism or repeated irritation and sometimes as the result of auto-intoxications. The treatment of this latter condition consists in removal of the cause, rest and a compressing bandage. If the effusion is not absorbed incision is required.

Chronic noninfective bursitis results from prolonged irritation of a bursal sac. It is best exemplified in "housemaid's knee." Chronic thickening of the sac wall is apt to be present and recurrence easily takes place. Curative treatment of the chronic cases demands removal of the bursa. This may be done under local anesthesia. The anesthetic should be carried around all of the sac as its deeper parts are most sensitive. Often the inflamed sac may be removed without opening it. Excision of the bursa is good routine treatment for these cases because many of them are tuberculous.

Other methods of treatment are incision, scarification of the lining, and compression by means of adhesive strapping; injection of tincture of iodin or iodoform emulsion; and incision, scarification, and injection of iodin. These latter measures are of value in deep-seated bursæ the removal of which might entail damage to tendons.

Tuberculous bursitis should be treated by dissecting out the bursa and at the same time searching for any neighboring tuberculosis which might be removed.

THE SKIN AND ITS APPENDAGES

TRAUMATISMS OF THE SKIN

Contusions of the skin may lower the local resistance or cause slight wounds and permit the entrance of pathologic organisms. For this reason, badly contused skin, especially in persons of feeble resistance or victims of chronic diseases, should be cleansed and covered with a copious warm, moist, antiseptic dressing. Failure to observe this precaution often results in extensive sloughs.

In the young and healthy to prevent the "black and blue" discoloration of contusion is often the desideratum of treatment. Much may be accomplished by applying cold and pressure as soon as possible after the injury. This checks the subcutaneous bleeding. After an hour or two of this treatment, absorption of the effused blood may be hastened by hot applications followed by massage.

Wounds of the skin should be treated by the principles already laid down (see Wounds, page 213). Aside from the viewpoint of cosmetics, a skin wound gaping more than 2 or 4 mm. ($\frac{1}{16}$ to $\frac{1}{8}$ inch) should be sewed or closed with adhesive straps.

Wounds of the face should be carefully closed. For this purpose fine horsehair or human hair or silk thread serves best. The skin apposition should be made as perfect as possible. A protective dressing of gauze is better than collodion; but it should be held firmly immobilized by adhesive plaster strips. At the end of thirty-six or forty-eight hours the dressing may be removed and the wound painted with tincture of iodin. This has the effect to increase hyperemia and minimize the scar.

Skin wounds which require drainage may be drained by a few strands of suture material made into a bundle and run from one end of the wound to the other. The subcuticular suture may be used to advantage in the skin.

Traumatic emphysema of the skin in which the subcutaneous areolar tissue is infiltrated with air or gas, usually requires no treatment other than attention to the wound of entrance. In rare cases it is possible for the emphysema to become so aggravated as to cause dyspnea. Under such circumstances a few incisions into the skin, made with aseptic care, allow the air to escape.

Burns.—The treatment of burns is not yet upon a satisfactory basis. In severe and extensive burns the surgeon realizes the helplessness of his art. In the most superficial burns of areas of more than two-thirds of the body, death usually results. Most cases, involving half of the area of the body, are fatal; and often when more than one-third of the surface is affected, death ensues. A fatal outcome is most common in the very young, the very old, debilitated persons, alcoholics and persons of highly sensitive nervous system. The indications of treatment are to combat shock, eliminate toxins, prevent infection, promptly treat ulcer of the stomach and intestine and heal denuded areas. In burns which are so small as not to cause appreciable shock, the patient recovers under almost any method of treatment. In the larger burns, treatment is so important that it often determines the difference between death and recovery.

In burns of a smaller area the patient will be made more comfortable by some application which excludes the air. For this purpose vaselin, olive oil, lard or other bland ointment or fixed oil should be used. The comfort of the patient will also be contributed to by adding some mild alkali, such as bicarbonate of soda. Linimentum calcis (carron oil), which is a mixture of equal parts of lime water and linseed oil, is a valuable application. This is spread on cotton cloth and laid on the burned area. These dressings should be renewed at least once daily.

Burns of the second and third degree, in which destruction of skin has taken place, should receive antiseptic treatment. Blebs should not be punctured and drained as the serum which they contain is a soothing dressing. Necrotic skin should be removed if it is detached; and gauze should be applied, wet with a saturated solution of boric acid combined with one-third alcohol, or a 2 to 5 per cent. solution of acetate of aluminum may be used. If there is much discharge the dressing should be changed oftener than once daily. As necrosis occurs, sloughing tissue should be removed. Dichloramine-T dissolved in chlorinated eucalyptol, in 5 per cent. strength, is most useful. The solution of sodium hypochlorite made after the method of Dakin (page 60) is effective. Burned surfaces kept constantly irrigated with this solution heal promptly and infection is prevented.

Better than depending upon antiseptics is asepsis, secured by frequent cleansing of the surface.

A soothing and protective dressing, which gives comfort to the patient, consists of 100 Gm. (3⅓ ounces) of petrolatum, to which are added 1 c.c. (15 minims) each of oil of thyme, oil of geranium and oil of origanum. An ointment of 3 Gm. (45 grains) of ichthyol, 8 c.c. (2 drams) of olive oil, and 90 Gm. (3 ounces) of lanolin, is useful. Another effective ointment consists of 100 parts petrolatum, 10 parts boric acid, and 3 parts balsam-of-Peru. An infected slough may be treated with 2 per cent. solution of chloride of zinc. Parts which have become charred and mummified may be treated with tar ointment.

The pain of burns of the limbs may be relieved by artificial hyperemia, induced by an elastic band above the burn. This not only relieves pain but promotes healing. Pain is also relieved by cool applications. Water, containing one-fourth alcohol, applied at a temperature of 10° or 16°C. (50° or 60°F.) on compresses which are changed every five minutes, or oftener, is most grateful.

In burns of variable areas, the above treatments may be used, or the treatment given below for extensive burns may be applied. An effective application is a 1 or 2 per cent. solution of picric acid. This is made of 6 Gm. (1½ drams) of picric acid, 60 c.c. (2 ounces) of alcohol, and 250 c.c. (9 ounces) of water. It is applied on flat pieces of cotton cloth or several layers of gauze. The gauze is held on by a bandage; and the whole dressing is covered with oiled paper to exclude the air. The gauze is kept constantly moist with the solution, and is changed every third day.

For larger areas a weaker picric acid solution should be used. Large areas should be dressed with ½ per cent. solution (picric acid 4, alcohol 60 and water 760 parts). A solution stronger than 1 per cent. need not be used. Picric acid treatment should never be combined with ointment. The parts should be cleansed of débris and washed with sterile water or boracic acid solution. During the first few hours or days, the patient should receive the immersion treatment described below. After he is comfortable and fatal shock has been averted, the burned surface should be dried and covered with pieces of soft cotton cloth soaked with the picric acid solution. These pieces

should be cut in strips so that they may be applied smoothly. A layer of cotton should be applied over this; and the dressing retained by a loose bandage The dressing may be left undisturbed for two, three or four days. It should be removed if it is soaked with discharges, or is becoming painful. After its removal, the skin should be cleansed by spraying with peroxid of hydrogen. It should then be dried, and another picric acid dressing applied.

The liquor cresolis compositus, of the U. S. Pharmacopeia, is a valuable application. The burns should first be washed with a 1 per cent. solution in water to remove débris and cleanse the skin. The parts should then be dressed with smooth pieces of cotton cloth soaked with this solution, or with a 1 per cent. cresol ointment. The dressing should be covered with cotton and changed every four or five days.

The use of dry dressings has proved satisfactory in the hands of some surgeons. My own observation is that it is painful and unsatisfactory. The area is cleansed with warm salt solution and dried with sterile gauze. The whole burned surface is then covered with stearate of zinc powder. No other dressing is applied. As serum exudes through the powder, the moist area is again dusted. This treatment is continued until the whole area is covered with a crust of powder. If pus lifts up any part of the crust, it should be removed, the area cleansed with saline solution, and again dusted with the powder. Such surfaces carefully exposed to the rays of the sun seem to heal more promptly.

A soothing application is a saturated solution of baking soda in water, to which 2 per cent. of corn-starch powder is added. Ichthyol 1 part, olive oil 15 parts, and lime water 15 parts, is soothing during the acute stage.

For more extensive burns, treatment with chloraminated oil (5 per cent. dichloramin-T in chlorinated eucalyptol) is highly satisfactory. A single layer of wide-meshed paraffined gauze or mosquito netting is placed over the burned area and the oil is sprayed over this. No other dressing need be applied, and the open air treatment should be employed. This simple dressing may be changed daily.

In extensive burns, the important thing is the treatment of shock. For this purpose all of the measures available for meeting this condition should be considered (see Shock, page 213). Above all, the patient should not be permitted to suffer pain. A mild psychic and sensory numbness should be induced with morphin, hyoscin, scopolamin or other drugs. Elimination should be hastened by the introduction of fluids by proctoclysis or other means.

A depressed patient may wisely be given at once an injection of 1 c.c. of pituitrin, 0.01 Gm. ($\frac{1}{6}$ grain) of morphin, and 0.0006 Gm. ($\frac{1}{100}$ grain) of hyoscine. There is an old saying to the effect that cases of burns that do not sleep the first night, die. This may not be wholly true, but it is true that pain means shock, and shock is the fatal phenomenon in burns.

The diet should be fluid, and the symptoms of gastric and duodenal ulcer should be watched for. In desperate cases with duodenal or gastric symptoms, no food should be given by stomach for two or three days.

The most satisfactory treatment of the burned surface is by immersion in a bath of water. *Hydrotherapy* has contributed more to reducing the mortality in these cases than any other method of treatment. The continuous warm bath treatment excludes air, numbs the sensory nerve endings, preserves the bodily heat, induces local hyperemia at the seat of the burn, avoids fluctuations of the temperature of the body, provides perfect drainage whereby septic absorption is obviated, and avoids the painful process of changing dressings. All of these conditions are the essentials for saving

life in desperate cases of burns. The first report of this treatment is that of G. Passavant (Deutsche Klinik, Nos. 36, 38 and 39, 1858), who applied the method on Sept. 14, 1857 to a number of patients. The water should have a temperature not below 38°C. (100°F.). Only the burned parts need be immersed. A bath-tub is used. As the water buoys the body there is little need of pillows or cushions. A hammock of muslin, transversely across the tub, serves for a head rest. In some cases the whole body may rest in such a hammock. By frequently changing the water the best possible cleansing and drainage are secured. In extensive burns, complicated with shock, the bath should be of warmer water, about 46°C. (115°F.). For the night the patient may be taken from the bath and put between dressings of vaselin, lime liniment, stearate of zinc powder, or some other bland material. If the whole circumference of the trunk is burned the dressing should be placed upon the bed before the patient lies upon it. Burned skin surfaces should never be permitted to lie in contact. An air or water mattress is of help for these cases of extensive burns.

There are many other means and materials which may be employed in the treatment of burns. As occlusive substances, may be mentioned collodion, glycerite of starch, soft paraffin, white lead plaster, mucilage of tragacanth and silver foil. Of the antiseptic ointments, are chloramine, boric acid, ichthyol, lead carbonate, lead oxid, lead subacetate, zinc oxid, resin cerate and compound resorcin ointment. Picric acid is one of the most useful applications in burns. Powders to exclude the air, absorb discharge, and keep the pressure of dressings from the skin in burns of the first degree, or any of the bland dusting powders, such as corn starch, precipitated zinc carbonate, prepared chalk and wheat flour, are useful.

The *paraffin occlusion treatment* of burns possesses certain advantages in these distressing injuries. Many preparations containing paraffin as the base have come into use. "Redintol," "parawax," "cerelene," "hyperthermine," "parresine," "mulene," "ambrine," paraffone" and "sandfortol," are some of the proprietary names. These substances are prepared by making a waxy mixture of paraffin, combined with vegetable waxes and resins. A compound is produced which is plastic, adhesive and elastic. The addition of 2 per cent. of eucalyptol is recommended.

One of these compounds is made of paraffin (melting point 48°C.) 97 per cent., asphalt 0.25 per cent., Japan wax 0.5 per cent., gum elemi 0.25 per cent., eucalyptol 2 per cent.

The formula used in the Western Pennsylvania Hospital is: Paraffin 70 Gm., liquid petrolatum (U.S.P.) 3 c.c., white beeswax 10 Gm., rosin 7 Gm., resorcin 0.2 Gm., Sudan III 0.05 Gm., and alcohol (95 per cent.) 10 c.c. The petrolatum and the paraffin are melted together. The resorcin is dissolved in the alcohol and added slowly to the melted mixture while being stirred. The heat is continued. The alcohol evaporates. The beeswax is added and stirred in until melted. Next the rosin is added and stirred while the heat is continued. Gum benzoin and other ingredients which are useful in skin affections may be added if desired.

The value of the application seems to be increased by the addition of an antiseptic. Beside the above agents, scarlet red and flavine have been sucesssfully added to the paraffin.

A perfectly satisfactory paraffin film may be made of paraffin (melting point 49° to 50°C. = 120° to 122°F.) 97.5, olive oil 1.5, asphalt 0.25. The compound should melt at about 47°C. (117°F.). It should be applied at a temperature of about 60°C. (140°F.). An analgesic effect is secured when the application in fluid form is made to a dry burned surface.

Before applying these substances the burned surface should be cleansed. If infection is present, it is best controlled with the application of chlorazene ($\frac{1}{8}$ to $\frac{1}{4}$ of 1 per cent.) or mild calcium hypochlorite solution. After the surface has been made germ-free, by antiseptic treatment, it should be dried. This is best accomplished by means of a hot-air electric drier. This instrument directs a stream of warm air against the denuded surface until it is thoroughly dried.

The dry surface is then sprayed with the melted paraffin compound. For this purpose a special sprayer may be employed. This apparatus keeps the substance at a temperature at which it maintains the liquid state. The whole surface is covered by the spray. The application soon solidifies and and forms a shiny coating. In the absence of the spray apparatus the application may be made with a soft camel's hair brush. As soon as the first coat has hardened, a thin flat layer of absorbent cotton is applied, and over this a second coat of the dressing mixture is sprayed or painted. The application should extend onto the healthy skin around the burned area.

A dressing of absorbent cotton, covered with several layers of gauze, and held on by a roller bandage, should complete the treatment. The dressing should be removed daily, and a similar treatment and dressing reapplied; washing with antiseptic solution, drying the surface with heated air and applying a layer of cotton, adding a second application of paraffin compound, dressing with cotton and gauze, and retaining all with a roller bandage.

Mixed *vaccines* are reported to be useful in combating the infection in burns. If the polyvalent vaccine is not effective, an autogenous vaccine is recommended. The value of this treatment has not yet been positively determined.

The *prevention of deformity in the healing of burns* deserves especial attention. Deformity is caused by the contracture of new connective tissue. The smaller the deposit of new connective tissue the less will be the later contracture. For this reason burns should be made to heal as promptly as possible. The longer a granulating surface remains uncovered with skin the greater will be the contracture deformity. Skin grafting should be used on all but the smallest granulating areas.

It is doubtful if massage and fibrolysin have much value. If skin grafting is not practised or if infection persists or sloughs are present, much still may be done to prevent contraction. The parts, if near a joint, should be kept in the position which most strongly antagonizes contraction. This may be done with bandages or splints. If the burned area is on the flexor side of a joint, the joint should be kept fully extended; if it is on the extensor side the joint should be kept flexed. By applying adhesive strips across the burned area, drawing the edges together, the skin is caused to grow more rapidly and the size of the area is reduced. Such adhesive strips may be applied directly upon the skin and the granulations. They should pass in such directions as to reduce the size of the area most effectively. Not more than three-fourths of the area should be covered. Interstices between the strips should be adequate for the escape of discharges. The gauze dressing should be applied over the adhesive. The strips should be removed and renewed 2 or 3 times weekly.

After burns have resolved into granulating surfaces, the sloughing tissue having come away, the treatment becomes that of an extensive ulcer or granulating wound (see Wounds with Loss of Substance, and Granulating Wounds, page 220). Too much time should not be given to the tentative treatment of these surfaces. Skin grafting and plastic operations should be practised. This is important because the process of epithelial proliferation from the

periphery is slow; and while it is going on, the scar tissue is becoming firmer and the ultimate nourishment of the overlying skin becoming jeopardized by the constriction of the blood-vessels.

Burns from dry heat, hot fluids, acids and *caustics require* about the same treatment. If burns from chemicals are seen soon enough the burning substance should be removed as quickly as possible, and chemical antidotes should be applied to neutralize any of the unremoved cauterant. Acids should be washed away and neutralized with alkalies, and alkalies with acid solutions.

Sunburn is treated with soothing ointments or dusting powder. A thick cream of lead carbonate in linseed oil is grateful, but should not be used over too large an area because of the possibility of lead poisoning. Tincture of benzoin is an agreeable application.

The same treatment as used in intertrigo is effective. Calamin-zinc-oxid lotion is used. As a preventive pure calamin powder stops the actinic rays of the sun. The lotion is as follows: powdered calamin 12 Gm. (3 drams), zinc oxid 12 Gm., glycerin 1 c.c. (15 minims), alcohol 2 c.c. (30 minims), and water enough to make 250 c.c. (½ pint). A powder which may be used with good effect is: boric acid 4 Gm. (1 dram), zinc oxid 8 Gm. (2 drams), and powdered talcum 20 Gm. (5 drams).

Time cures sunburn.

INFECTIONS AND INFLAMMATIONS

Erythema Intertrigo.—The skin should be cleansed with water and soap, dried, and dusted with a soothing antiseptic powder such as zinc oxide or diluted boric acid (see Sunburn, above). The parts should be kept separated by gauze. The prognosis is good.

Erythema Multiforme.—Constitutional treatment should remove the cause. Cooling and astringent lotions or mild antiseptic powders should be applied locally.

Erysipelas.—(See page 262.)

Dermatitis Venenata (Skin Poisoning).—Treatment is the same as that of acute eczema. Soothing lotions should be applied. Linimentum calcis, saturated solutions of boric acid, bicarbonate of soda, 2 per cent. solution of menthol in water or alcohol, are useful.

In *ivy poisoning* and *sumac poisoning*, the skin is irritated by an oil from the plant. It does not spread unless the area which it originally covered is extended by scratching, by the rubbing of the clothing, or by other mechanical contact; but because of the tenacious property of its irritation it may be carried from one part or person to another by fingers or clothing, retaining its activity for a long time, and relief being found only by removing the noxious oil. Treatment must be based on dissolving the offending oil and removing it. The oil may be washed from the skin just the same as any other oil. This is best done with soap, warm water and a brush. An alkaline bath may be used for the same purpose. After thoroughly cleansing the part, it should be washed with alcohol or ether. The clothes likewise should be cleansed.

The oil is precipitated and rendered inert by permanganate of potash and by lead acetate. One of these should be applied in solution after the cleansing, to neutralize what oil remains. If the treatment is not begun early some dermatitis results from the irritation of the poison and from infection with bacteria added to the disease. This infection may be treated with ointment of yellow oxid of mercury. If itching and discharge are distressing they are relieved by a lotion of 4 Gm. (1 dram) of calamine,

2 Gm. (½ dram) of phenol, 12 Gm. (3 drams) of zinc oxid, 15 c.c. (4 drams) of glycerin, 120 c.c. (4 ounces) of lime water and 120 c.c. (4 ounces) of dilute solution of subacetate of lead. Or they may be relieved by a 15 or 20 per cent. ointment of subgallate of bismuth.

In *primrose poisoning* the same treatment is effective as is used for poison ivy. The poison may be washed away with alcohol, ether, or chloroform.

A strong solution of magnesium sulphate is one of the best applications for the dermatitis which follows these poisons. It allays the irritation.

Dermatitis Exfoliativa (Characterized by the Exfoliation of Fine Paper-like Scales).—Soothing ointments, such as of zinc oxid are used.

Infectious Eczematoid Dermatitis.—The treatment of this disease is important for the surgeon because of its relation to infected foci and its tendency to spread to other parts. The general health of the patient should be improved. Cure is often secured by applying a paste of 0.6 Gm. (10 grains) of salicylic acid, 8 Gm. (2 drams) of zinc oxid, 8 Gm. of starch, and enough vaselin to make 30 Gm. (1 ounce). The disease often yields to the application of a solution of 7 parts zinc sulphate, 2 parts copper sulphate, and water 200 to 600 parts. This solution should be applied on a compress every hour or two. Where the disease develops about a discharging wound or sinus, the skin should be treated with an ointment containing sulphur or ammoniated mercury. In obstinate intertriginous infections, such as occur back of the ears, a 10 per cent. silver nitrate solution is recommended.

Frost-bite.—A person who has been subjected to a low degree of cold for a dangerously long period, after passing through stages of feelings of coldness, exhilaration, torpor and numbness, finally becomes overwhelmed with a desire to sleep. To yield to this impulse is fatal. In this stage or the earlier stages the patient should be taken to a cool room and rubbed with cold water. Surface friction should be given with wet cloths, and the putient put in a bath having a temperature of 16° to 18°C. (61° to 65°F.). The temperature of the water should be raised gradually (within two or three hours) to 30°C. (86°F.), and then to 38°C. (100°F.) and the patient removed. Symptomatic indications should be met. Diffusible stimulants, if urgently called for, should be used. Hypodermic injections of ether, or camphor are useful. Hot drinks are to be given when the patient can swallow. The chilled extremities should be wrapped in wet cloths, having a temperature of about 30°C. (86°F.).

When the *frost-bite* is distinctly local and not accompanied with constitutional symptoms, pains should be taken to secure gradual and not quick reaction. The part should be immersed in ice water and given massage or it should be rubbed with snow. When the temperature of the part is normal but there is numbness present, it should be rubbed with stimulating liniments such as camphor or alcohol. The air may be gradually warmed. The skin should be cleansed, and, when gangrene threatens, it should be kept covered with aseptic gauze. Any wounds or scratches should be treated antiseptically.

Chilblain (pernio), the later effects of cold, may be relieved by applying warm water, drying the part, and dusting with calamin powder or applying boric acid ointment, containing ½ per cent. menthol. Cases seen later are treated by immersing the parts in a hot saturated solution of alum. A mild astringent antiseptic ointment may be rubbed in. For this purpose ichthyol (10 per cent.), balsam-of-Peru, phenol ointment, iodin ointment, compound resorcin ointment or oil of turpentine are used. Painting the part with collodion, mixed with a powder such as iodoform or europhen,

is of service. When ulceration is present antiseptic dressings should be used.

Pernio may be prevented by protecting the hands and feet from cold, and maintaining the best possible state of health. In rebellious cases the region should be painted with tincture of iodin, and as soon as it is dry swabbed with pure ichthyol. Absorbent cotton should then be applied in a smooth layer. A gauze bandage should hold the cotton in place; and over all should be drawn a cotton stocking or glove. This dressing is left dry and undisturbed for five days. Some cases are helped by a mild galvanic current—2 or 3 milliampères every second or third day. The positive pole should be applied to the affected part, and the negative pole to the region of the supplying nerve trunk.

Dermatitis Herpetiformis.—Improve general health. Apply soothing lotions. Applications which are used for pruritus are effective here Mild antiseptic solutions, ichthyol (5 per cent. solution), 0.5 per cent. carbolized oil and lime water are of service. Prognosis: curable, but recurrences common.

Urticaria (Hives, Nettle-rash, Characterized by Ephemeral Pink or Whitish Wheals, with Itching).—Remove cause. If of intestinal origin, as is usually the case, a laxative should be given, and followed by abstinence from food for a few days until the disease is well. If food is taken it should be much restricted. Atropin is useful. The intense local itching may be relieved by menthol (1 to 10 per cent. in water, alcohol or oil), vinegar, or phenol (1 per cent. solution). Camphor and chloral hydrate (½ to 1 dram of each in an ounce of ointment), betanaphthol (10 per cent. ointment), borax, salicylic acid (20 per cent. powder or ointment), hot or cold baths sometimes give relief. The same applications as are used in pruritus are effective in urticaria. The injection of autogenous or kindred blood-serum is reported to give good results in chronic cases.

Lichen Planus (Characterized by Flat, Angular Papules).—Improve general health. Arsenic and alkaline diuretics internally are often of advantage. Locally, alkaline baths, oil of cade, vinegar, phenol (1 per cent. solution) and tar water are employed. Unna recommended hydrargyri chlor. corrosiv., 0.06 Gm. (gr. i); phenol, 0.3 to 0.6 Gm. (gr. v to x); unguenti zinci oxidi, 30 gm. (gr. 500). Much the same treatment as is used in eczema is employed. Prognosis good.

Lichen Ruber (Reddish Papules, Capped with Scales; Itching).—Improve general health. The local treatment used in psoriasis and ichthyosis is applicable. Menthol and phenol are of especial value. Soft soap, glycerin, mild ointments and ointment of sodium bicarbonate are of service to relieve the dryness of the skin. Prognosis good when disease is limited, bad when generalized.

Furunculosis (Furuncle, Boil).—The local treatment of a fully developed furuncle with an abscess is based upon drainage, asepsis and increasing the hyperemia. This latter may best be done by suction cups. Hot applications are also of service. A hot solution of boracic acid (4 per cent.) is useful both for its hyperemic and antiseptic effect. An old method is the application of sodium chlorid made into a paste with turpentine. A 50 per cent. solution of ichthyol is often effective. In recurring furuncles a search should be made for the primary focus of infection. In neck infections the scalp should be examined and infection if found treated with ointment of sulphur and salicylic acid.

When an abscess has developed it should be opened and treated by the suction cup (see Hyperemic Treatment of Inflammations, page 229). By this method a cure may be secured in five days.

Furuncle, if seen in its earliest stage, may be aborted in the first two days by cauterizing its center. The painful area should be picked up between the fingers, and the centre will be recognized as a white spot. This is the mouth of the hair follicle in which the furuncle has developed. With a 2 per cent. novocain solution the centre is anesthetized. As soon as sensation is destroyed the actual cautery, preferably a heavy needle heated red hot, is passed into the center of the infection. A needle may be stuck into a piece of wood or cork for a handle. Sterilization and hyperemia are produced. The direction of the surrounding hair should be noticed and the needle passed in the same direction.

If the center of a furuncle has become thoroughly softened, an excellent treatment consists in sharpening a piece of wood, like a wooden toothpick or a match, dipping the sharpened end in phenol and carefully boring it into the center. This should be done slowly to get the anesthetic effect of the phenol; and the point should not be pressed beyond the abscess, in order that the natural inflammatory barrier against the infection shall not be broken. If the abscess is large some phenol may be introduced on a swab. Then a 10 per cent. ointment of salicylic acid is applied twice daily.

The germs are carried by the clothing to infect the adjacent skin. Complete cleansing of the skin is highly desirable, and it is for this reason that good results are gotten by washing the scalp, head, neck and trunk with soap and warm water, followed by boric acid solution which is allowed to dry on the skin, and then painting the affected region with tincture of iodin. By keeping the skin sterilized, spread of infection is prevented. If the whole surface is dressed three times daily with gauze wet with bichlorid of mercury solution, the skin may be kept sterile. Painting the skin with a 4 per cent. solution of formaldehyd is highly effective. The dressings should be destroyed and the hands washed after each dressing. It is not good practice to incise freely into a furuncle and cause a wound in the surrounding tissues which are invaded by virile leukocytes and antitoxins. Only the skin at the very central point should be opened. If this is done it will be seen that the furuncle is a self-limiting disease. After this central opening has been made, and phenol applied, the suction cup may be used, before putting on the antiseptic dressing. If the surgeon is bent on free incision the only incision that should be used is a circular one which completely removes the whole indurated area. This is usually unnecessarily radical treatment.

During the first few days after an opening has been made the flow of serum to the region may be increased by a poultice made of gauze saturated with normal salt solution containing 1 per cent. of sodium citrate. This should be applied hot and covered with rubber dam.

Large furuncle which threatens to become a carbuncle, is best treated by passing the needle of a hypodermic syringe through the sound tissue outside of the disease, and locating the point just under the center of the abscess. The tissue is then injected with 3 per cent. solution of novocain. After about five minutes, when the furuncle has become anesthetized, the pus and necrotic material at the center should be removed with a curet, the cavity swabbed out with phenol followed by alcohol, the skin sterilized with iodin and the whole covered with a copious wet antiseptic dressing.

Other methods are the injection into the abscess of tincture of iodin or pure phenol and alcohol without evacuation. An antiseptic dressing (gauze wet with corrosive sublimate solution) should be kept over the abscess, and the surrounding skin should be kept clean. Constitutional treatment is important. The general health should be improved. Diabetes should be looked for. By keeping the surrounding skin cleansed with alcohol, and by painting suspicious spots with iodin, recurrences may be prevented.

The most effective constitutional treatment has been *vaccination* with cultures of Staphylococcus albus and Staphylococcus aureus. Either autogenous or polyvalent stock vaccines may be used. The beginning dose is 200,000,000 organisms every seven days. This dosage may be increased to 400,000,000. The internal administration of calx sulphurata is possibly of use. The drug should be begun with 0.015 Gm. (¼ grain) three times daily, and increased to the limit of tolerance. The prognosis is favorable.

The use of baker's yeast has proved effective in furunculosis, acne vulgaris, acne rosacea, and other skin diseases. One half or a whole cake of yeast is given three times daily. If the effect is too laxative the amount may be reduced. If too much gas is produced, the yeast may be killed by heating before it is administered.

Impetigo Contagiosa (Characterized by Rapid Formation of Vesicopapules, usually on Scalp, Face and Hands of Children).—Each pustule should be evacuated, the skin cleansed with water and soap and a mild antiseptic applied. A valuable poultice is made of powdered starch 15 Gm. (½ ounce), dissolved in 30 c.c. (1 ounce) of cold water; to this is added 180 c.c. (6 ounces) of boiling water; this should be stirred rapidly into a paste, and 15 gm. (½ ounce) of boric acid added. This warm mass is placed between two layers of thin cotton cloth and applied as hot as the patient will bear it. After the crusts are softened by this treatment, an effective application is made of equal parts of zinc oxid ointment and ammoniated mercurial ointment.

It is possible in some cases to abort the disease by applying silver nitrate. A most valuable routine application is 20 per cent. silver nitrate solution. After swabbing with the silver solution, a mild dusting powder should be applied.

Weak alcoholic solutions are most effective on the bearded skin.

A useful remedy is the ordinary *carbol-fuchsin* stain of Ziehl, composed of 1 fuchsin, 10 alcohol, 5 phenol and 100 distilled water. This is simply painted on the crusts every day.

Powders are usually to be preferred to ointments. One of the best remedies is sunlight. For *bullous impetigo* of the newborn it is the best remedy.

Perlèche (a Highly Contagious Impetigo-like Infection of the Lips of Children).—The disease should not be mistaken for a mucous patch and treated for syphilis. Prophylaxis is important. Common drinking cups, lead pencils, etc., should be avoided as these have often spread contagions. The lesions are promptly cured by painting every day or every second day with 10 per cent. solution of iodin in alcohol or pure copper sulphate seems to be quite as efficacious.

This common infection of the corners of the mouth of infants is cured by applying warm boric acid solution followed by an ointment composed of equal parts of ointment of ammoniated mercury and ointment of zinc oxid.

Other children should be protected from contagion. Prognosis is good.

Ecthyma (one or more Large, Flat, Inflamed Pustules).—Improve the personal hygiene. Cleanse the skin, remove crusts, apply antiseptic and stimulating medication. Treatment similar to that of impetigo contagiosa is applied. Phenol, boric acid or compound resorcin, ammoniated mercuric ointments are of value. Prognosis favorable.

Herpes Simplex (Characterized by One or Several Pinhead to Pea-sized Vesicles on an Inflamed Base; Occurring on Face and Genitals).—Adjacent local disturbances and constitutional defects should be corrected. By carefully pricking and evacuating each vesicle and keeping it wet with spirits of camphor, the course of the disease, which is usually from five to

ten days, may be shortened. Painting the surface with tincture of benzoin is useful. Several coats should be painted on several times daily while the parts are gently stretched. The parts should be kept free from irritation. Flexible collodion may be mixed with subgallate of bismuth or europhen and painted on. The common treatment is the use of soothing ointments such as zinc oxid. Herpes of the genitals should be treated by cleansing the parts, keeping them dry and free from discharges and applying calomel powder or astringent washes. Recurrences are apt to take place. A mild galvanic current is useful in rebellious and recurrent cases.

Herpes Zoster (Shingles; Characterized by Groups of Vesicles on an Inflamed Base, Following the Course of Distribution of a Cutaneous Nerve).—The application of a 95 per cent. solution of phenol followed by alcohol as soon as the skin turns white, gives relief in most cases. This should be followed by a mild ointment such as zinc oxid. The hygiene of the patient should be improved. The vesicles should be protected. A fine powder containing camphor or menthol is useful. The parts involved should be covered with a layer of gauze over which clean cotton wool is held by a bandage. A powder of zinc oxid, boric acid and talcum is much used. Painting the diseased skin with collodion is recommended. The stimulation of the nerve trunks, supplying the diseased area, as they emerge from the spine is of service. This is best done by the galvanic current or by mechanical vibration. The disease is usually self-limiting and runs its course in a few weeks. Rebellious cases may be treated by a mild galvanic current.

Pemphigus (Acute or Chronic; with Bullæ Usually in Crops).—Constitutional treatment should aim to improve the general health. The internal use of arsenic, up to the limit of toleration, seems to be of value. The blebs should be evacuated, and mild soothing applications used. Zinc stearate, boric acid and starch (1 to 4), bran and subgallate of bismuth and zinc stearate (1 to 4) are of service. Prognosis depends on general condition of patient. If the itching is a prominent symptom, the remedies used in pruritus are applicable.

Eczema (Characterized at First by Erythema, Vesicles, Papules and Pustules with Infiltration, Heat or Itching; and Ending in Serous or Purulent Discharge and Crusts).—If the disease has any constitutional etiologic factor, it should be discovered and eliminated. Eczema not of a purely local nature demands attention to the general health. If a definite cause cannot be found it may be assumed that the disease springs from absorption of toxins from the intestine or mouth. Restriction of diet and fresh air are essential. Especial errors of diet such as the use of alcohol, coffee and tea, or poorly balanced diet, should be corrected. Internal medication is rarely necessary. Constipation and imperfect salivation should receive attention. Diabetes, tuberculosis, varicose veins and local disturbances of circulation should be looked for.

The local treatment depends upon the character of the disease. In acute and subacute cases the application of water seems to aggravate, and it should be used only for necessary cleansing and then mollified by the addition of starch. Crusts should be softened with oil or ointment and washed off with bicarbonate of soda or with borax solution. In the acute cases a soothing protecting application should be used. Lotions should be used in moist eczema and salves in dry eczema. The following mixture is of service in moist eczema: calomel 1 Gm. (15 grains), mucilage of tragacanth 2 Gm. (30 grains), lime water 150 c.c. (5 ounces). This should be applied for twenty minutes several times daily, followed by oxid of zinc ointment. Zinc oxid 4 Gm. (1 dram), glycerin 4 Gm., lime water 180 Gm. (6 ounces) is a good application. A

lotion much used in England is a solution of 7 per cent. of salicylic acid in liquor plumbi subacetatis: 15 c.c. (½ ounce) of this is added to 230 c.c. (8 ounces) of milk, and applied every four hours. Liquor plumbi subacetatis, saturated solution of boric acid, borosalicylic solution, 2 per cent. picric acid solution, weak alkaline solutions and glycerin and lime water (1 to 20) in the later stages are all useful. If the itching is not relieved, antipruritics may be combined with any of these. For this purpose, 2 per cent. phenol solution, camphor water, or 1 per cent. menthol solution may be used. Antiseptics are not necessary in simple eczema, but in the impetiginous form mild antiseptics are useful.

Powders are of service when the moisture is slight, in vesicular eczema, and in acute erythematous eczema. Starch powder, carbonate of zinc, bismuth subnitrate, bismuth subgallate and oxid of zinc are good. A valuable powder is boric acid 1 part, lycopodium 2 parts, stearate of zinc 3 parts. This is always valuable as a drying dusting powder for any region. Another having antipruritic properties is zinc oxid 15 Gm. (½ ounce), powdered camphor 6 Gm. (1½ drams), powdered starch 30 Gm. (1 ounce). Compound tincture of benzoin relieves itching.

Ointments usually do not give comfort in acute eczema, but in some cases they prove especially efficacious. Any of the powders recommended above may be used in ointment form. Ointment of zinc oxid to which is added 5 per cent. of ichthyol is often of service. Diachylon ointment is used.

For softening the thickened skin the following mixture may be applied every five days: 15 c.c. (½ ounce) each of tar water, alcohol and glycerin and 5 c.c. (75 minims) phenol. This should be painted on with a soft swab. On the intervening days zinc oxid and calamin lotion should be used.

Chronic eczema of the dry type requires stimulating applications. The skin should be cleansed with soap and water. Green soap is of especial value in softening the skin. It may best be used in alcoholic solution. A useful ointment is of 2 Gm. (30 grains) salicylic acid, 30 Gm. (1 ounce) zinc oxid, 30 Gm. corn starch and 60 Gm. (2 ounces) soft paraffin. Stimulating remedies are pine-tar, birch-tar, oil of cade, compound resorcin ointment. Tar should be used with caution, beginning with 10 per cent. lotion or ointment and increasing the strength as tolerance is observed. It may be covered with a dressing and bandaged. Salicylic acid ointment, ointment of ammoniated mercury, balsam-of-Peru, ichthyol (5 to 10 per cent.), silver nitrate solution (2 to 5 per cent.) and compound resorcin ointment are of service in many cases. The silver solution is useful at the junction of skin and mucous membrane. Salicylic acid and other irritating substances should not be used if the skin is red and irritated. For seborrheal eczema, sulphur is used. The internal administration of thyroid extract cures some cases.

Tar irritates and aggravates acute moist eczema; but in most cases of the chronic moist eczema tar will convert it into the dry form. Coal tar in solution is used. It need not be preceded by washing or other dressings. The moist patches should be painted with tar water. The surface will become dry and scabbed in four or five days. Then a 2 per cent. salicylic acid salve should be rubbed in twice daily. After a few days when the scabs have become soft the part is washed with soap and warm water.

Chronic eczema requires especial inquiry into the general personal hygiene. Irritating applications should not be used. With moist, red or itching skin sedative lotions seem to give more relief than ointments. The following mixture is useful: 1 Gm. (15 grains) zinc oxid, 2 Gm. (30 grains)

calamin powder, 10 c.c. (3 drams) lime water and 25 c.c. (1 ounce) olive oil. This should be applied with a soft swab, or a layer of gauze held on with a thin bandage. Thick dressings should not be used.

Purulent eczema should be treated for half an hour daily with a mild antiseptic solution. If boric acid solution or liquor antisepticus (U.S.P.) is not effective, 10 per cent. chloraminated oil may be used. After the suppuration is controlled, a soothing lotion should be applied.

If the skin is red and irritated the following ointment is useful: 30 Gm. (1 ounce) zinc oxid, 30 c.c. lime water, 30 Gm. olive oil, and 10 Gm. (3 drams) hydrated wool fat. This ointment may be applied thickly and then powdered with zinc oxid or corn starch.

Cracked and fissured patches at the corners of the mouth, on the lips, nipples, arms and vulva are best treated by phenol, followed by alcohol, or by 10 or 20 per cent. silver nitrate solution. Such applications may be made once a week. For itching eczema at the mucous membrane orifices, picric acid solution (in ¼ to 1 per cent. strength) is useful. Heat is effective in many cases of chronic eczema. The part is subjected to the heat of an oven at 100° to 115°C. (212° to 239°F.). The application is momentary, and made by passing the part back and forth a few times thrice daily. The treatment should be made a little longer each time, the part being subjected to the heat until the prickling sensation ceases and comfort ensues. The dry heat is followed by the application of a hot towel wrung out in boiling water.

Some cases yield to radium treatment (see Radiotherapy, Vol. III).

The *vaccine treatment of eczema* gives good results in many cases which are intractable to other measures. Autogenous vaccines are made from cultures taken from unopened vesicles and from beneath the crusts. Staphylococcus aureus, in pure culture, or mixed with Staphylococcus albus, or with streptococcus, are the organisms found. Large doses of the staphylococcus cultures must be used. L. S. Medalia (Boston Med. and Surg. Jour., Aug. 5, 1915) used doses as large as six thousand million.

For eczema of the *lips* and for *chapped lips* a useful application is the following: 2 Gm. borax, 30 c.c. glycerin, 30 c.c. rose-water, applied frequently. Another valuable treatment is the local application of compound tincture of benzoin, painted on the lips twice daily and followed by suet or cold cream.

In eczema of the *legs* the circulation should be improved and diseased veins supported. Collodion or gelatin dressings are of value. A mixture is made of 5 parts each of gelatin and zinc oxid, and 20 parts each of glycerin and water. Any of the other remedies may be incorporated with this. The limb is painted with this mixture; a gauze bandage is smoothly applied; and as each layer is put on it is painted with the mixture. This dressing may be left on for ten days or longer (see Varicose Veins of the Leg, page 448).

For the erythematous eczema of the *face* the following may be painted on and allowed to dry: bismuth subgallate 1, tragacanth 5, glycerin 2, water 92. Eczema of the *scalp* and ears may be treated with glycerite of borax, after removing crusts with oil and soap. Eczema of the *eyelids* is treated with citrine ointment.

Boracic acid ointment is useful in eczema of the *vulva*. Leukorrhea and diabetes must be corrected. Eczema of the *scrotum* requires a suspensory. Hot applications, followed by antipruritic lotions or powders, relieve itching. Tar has long been a favorite remedy. Solutions of silver nitrate are also of service.

Eczema of the *anus* requires the same constitutional treatment as is

given to hemorrhoids (see Hemorrhoids, Vol. III). If hemorrhoids, ulcers, or fissures are present they must be cured. Hot water will relieve the itching. Unguentum phenolis, unguentum picis liquidæ, 3 per cent. nitrate of silver solution, 2 per cent. salicylic acid in collodion, balsam-of-Peru, unguentum hydrargyri subchlorid, and 5 to 10 per cent. ichthyol ointment are useful.

Eczema of the *hands* is usually the result of some practice which is detrimental to the health of the skin. The "*bichloride eczema*" of the operating room and the eczema of dish washers are examples. Treatment demands that the causative practices must be discontinued or the hands protected by rubber gloves. Usually nothing more than removal of the cause is required. If some contact with water cannot be avoided, the hands should be dried and then rubbed with a fine oil such as cocoa butter. If medication is required it may follow the general lines already given. Prognosis is good if treatment is thorough.

In *hyperkeratotic eczema of the palms and soles*, the practices which have caused the eczema should be discontinued. A plaster made by impregnating mull with 5 per cent. salicylic acid in soap plaster should be applied to the palms. Over it are applied zinc oxid and an impervious dressing to exclude the air. This application is renewed every day until the skin becomes soft. To the soles should be applied a 10 per cent. salicylic acid ointment made with equal parts of lanolin and vaselin. After the skin has become softened the following ointment may be used: 4 Gm. red oxide of mercury, 4 Gm. camphor, 4 Gm. carbonate of lead, and 32 Gm. each of lanolin and vaselin.

Eczema *in children* requires attention to the diet, cleanliness of the skin, prevention of exposure to extreme cold, strong soap, irritating discharges, scratching, or irritation. The same remedies employed in adults, but with greater dilution, are used. For infants a valuable ointment is made of calomel 1 Gm., phenol 5 Gm., and zinc oxid ointment and vaselin, of each, 30 Gm.

Local treatment should not be attempted in infants till constitutional errors are corrected. Fresh air, simple clean food, and quiet are essential for infants. The general treatment is the main thing. Baths should be given with care lest they spread the disease. Scratching must be stopped. If the eczema is on the face a pasteboard cuff may be placed about the elbows which does not permit the arms to be bent enough for the hands to reach the head.

In some cases dietary idiosyncrasies must be considered. Changing the water, milk or other foods may be tried. Inquiry should be made into the feeding. Perhaps the child is getting too much or too rich milk. The nursing mother may need more exercise or less rich food. The child should have regular nursing at long intervals. Every four hours is often enough. The child should not be permitted to suck too long. If the child is taking too much rich milk, it may be given some barley water just before nursing. If no cause for the eczema can be found empirical changing of the diet should be tried.

Psoriasis (Chronic; Characterized by Thick, Imbricated, Adherent, Lustrous, Whitish Scales, Resting upon a Reddish Sharply Defined Base).—The important feature of treatment is the correction of hygienic errors. The patient should live as much in the sunlight as possible. Overeating, bad air, insufficient exercise, alcohol, tobacco, tea, coffee, improperly balanced diet, indigestion, defective elimination, toxemia from intestinal absorption, and defects of metabolism are among the conditions to be eliminated. When the causative factors are corrected, the disease will subside; but while this is

being done local treatment may be applied. Arsenic, as a constitutional remedy, seems to be of value in chronic cases. It is used in the form of liquor potassii arsenitis in doses of 0.2 to 0.6 c.c. (3 to 10 minims) thrice daily, or arsenous acid, 0.0015 to 0.004 Gm. (gr. $\frac{1}{40}$ to $\frac{1}{15}$), thrice daily, and should be pushed to its physiologic limit, and continued for some time after the symptoms have subsided.

The local treatment should begin with the removal of the scales with soap and hot water. If simple alkaline baths do not suffice, linimentum saponis mollis (U.S.P.) may be used for this purpose. This may be left on to macerate the scales. It has a positive curative value. A 5 per cent. solution of salicylic acid in alcohol is of service for the same purpose. Of the local remedies, tar is one of the most effective. The ointment should be diluted one-third. Oil of cade may be used in 10 per cent. strength in collodion.

If the skin is much congested soothing applications should be used. Usually stimulating remedies are called for. Chrysarobin is the most potent local remedy. The treatment of Dreuw consists in the use of the following ointment: acid salicylic 10, chrysarobin 10 or 20, oleum rusci 25, sapo viridis 35, and lanolin or vaselin 25. This ointment is used for five days, at the end of which time the patient begins to take hot baths daily. The baths are followed by rubbing in vaselin. This is continued for five days, and then if necessary the course is repeated.

Milder ointment is preferred by some dermatologists, who use 2 chrysophanic acid, 2 salicylic acid, 2 pyrogallic acid, 2 ammoniated mercury, and 30 each of lanolin, vaselin, and olive oil. The mild chrysophanic ointment is probably as effective as the stronger.

Another preparation is 8 Gm. (2 drams) kaolin, 15 Gm. (4 drams) each of corn starch and lanolin, 8 c.c. (2 drams) liquid paraffin, and 1 or 2 Gm. (15 or 30 grains) chrysarobin. This ointment may be used on the head, face, or hands, provided it does not get in the eye. By removing thoroughly with benzin, staining of the skin is avoided. It should be applied at night and removed in the morning. In other parts it need not be removed but may be left on all day.

In the most obstinate cases, 10 or 20 per cent. chrysarobin ointment must be used, and its absorption encouraged by inunction and by covering it with rubber cloth. It is not desirable to use chrysarobin on the face because of its stain.

Tar is of value in the form of pix liquida or oleum rusci. Oil of cade is useful incorporated with an ointment (10 to 50 per cent.) or it may be mixed with a fixed oil and saponified with sodium hydroxid. The ointment or soap is applied over night. For the face, scalp, and other exposed parts, ointment of ammoniated mercury (2 to 5 per cent.) is useful. In psoriasis of the *tongue*, chromic acid (1 : 50) is effective; or silver nitrate.

Other applications which are of service are pyrogallol (5 to 10 per cent. ointment), alkaline baths, ichthyol, ointment of lead iodid, resorcinol (3 per cent. solution with a little glycerin, or 8 per cent. ointment), and equal parts of tar ointment and sulphur ointment. An application which is effective in one case will not be effective in another or even in the same case at another time. The prognosis depends on general health and persistence of treatment; it is usually favorable.

Treatment by baths is one of the oldest methods. Simple warm baths of an hour or more each day are of advantage. Sweating, to macerate the skin, is another old and well-tried remedy.

The application of carbon-dioxid snow leaves some pigmentation but it seems to cure the lesions of psoriasis.

Excellent results have been obtained by exposing the diseased area to sunlight. If this cannot be done, artificial phototherapy may be applied by the mercury vapor light.

The intravenous injection of *foreign proteid*, such as *horse serum* and vaccines, is useful. *Typhoid vaccine* in doses of from 75 to 100 million every three or four days, for four or five injections, gives good results when combined with local treatment.

An effective treatment is by the use of *autogenous serum combined with chrysarobin*. The most intractable cases of many years' duration often yield to this method. The technic is not difficult. At each treatment 80 to 100 c.c. (2⅔ to 3⅓ ounces) of blood are drawn from a vein of the patient's arm by means of the hollow needle, made for this purpose. The blood is allowed to flow into a sterile glass bottle, which is placed in a centrifuge, having a speed of 1800 or more revolutions a minute. This precipitates the corpuscles and fibrin. The clear supernatant serum is drawn up into a syringe and injected at once either into a vein or into muscle. This amount of blood yields from 25 to 45 c.c. of serum. This treatment is given every three or five days. From four to six injections are given.

The serum treatment should be followed by the local application of chrysarobin ointment. This should be used in strengths varying from 2 to 10 per cent. The serum seems to produce some change in the tissues which renders them more susceptible to the action of chrysarobin.

Other dermatoses, such as eczema, dermatitis herpetiformis, chronic urticaria and lupus erythematosus, are benefited by this treatment. Psoriasis yields also in many cases to treatment with radium (see Radiotherapy, Vol. III).

Acne (Pimples; Papules, Pustules and Comedones from Inflammation of Sebaceous Glands; usually on Face).—The treatment of acne requires the discovery and elimination of the errors in personal hygiene which are responsible for the disease, just as in eczema. Usually this means correction of diet, exercise, breathing, elimination and sexual life. Anemia or other disease conditions should be treated.

Intestinal disorder is perhaps the most tangible cause of the disease. Regulation of diet will cure most cases. The following are to be avoided: fresh bread, macaroni, candy, cakes, pie, ice cream and other foods rich in cane sugar. The patient can usually be cured by restricting the diet for two or three weeks to vegetable soup, dry toast, milk, soft boiled eggs and orange or lemon juice, and following this by a restricted diet. The food should be slowly eaten and well chewed.

While the general health is being improved local treatment may be applied. Antiseptics are the effective remedies. Powders, lotions or ointments may be used alternately. The skin should be cleansed with soap and water, and, if it is acutely inflamed, soothing applications, such as are used in eczema, should be adopted. Most cases require vigorous treatment from the beginning, washing the skin, removing comedones, and the incision and evacuation of the pustules. Each tiny abscess should be treated. When the skin is oily and sluggish, suction cups should be used. This gives massage, improves the circulation, and empties the follicles. Faradic or galvanic electricity may be used to improve the circulation. If the lesions are acute the soothing lotions which are used in eczema should be employed. A good mixture is: calamin 2.50, zinc oxid 5, boric acid 4 and water 120. If the skin is dry 1 part of glycerin may be added.

If the skin is oily, lotions are to be preferred. Sulphur is a most valuable remedy. The following is useful: sulphur loti 10 Gm. (2½ drams),

spir. camphor. 12 Gm. (3 drams), sodii biborat. 8 Gm. (2 drams), glycerin 22 Gm. (6 drams), aquæ dist. ad 120 c.c. (4 ounces). This leaves a thin film after drying. A useful lotion is composed as follows: sulph. precip. 15, pulvis camphor. 0.50, pulv. tragacanth 1.25, aquæ calcis 60, aquæ rosæ 60. Another lotion is: sulphur precip. 8, glycerini 8, alcohol 30, aquæ calcis 30, aquæ rosæ 60.

In the ordinary case requiring soothing or stimulating treatment, ointments are used.

A valuable adjunct to treatment consists in applying hot boracic acid solution (3 per cent.) for half an hour daily before ointment is applied. A much used ointment is precipitated sulphur 4, in benzoinated lard and lanolin, 15 each. Where a stimulating dressing is required, resorcin in 2 to 10 per cent. ointment is of service. Mercury is used in the unguentum hydrargyri ammoniati (5 to 15 per cent. strength); or bichloride of mercury may be applied, 0.03 to 0.12 Gm. (½ to 2 grains) in 120 c.c. (4 ounces) of emulsion of almond. The prognosis is good.

Acne Rosacea (Chronic Inflammation, Especially of Nose and Cheeks, Often Associated with Hypertrophy).—This disease requires the same attention to constitutional treatment as acne and eczema. The first stage is treated the same as acne. Hot water should be applied for about ten minutes daily and followed by an application of some mild antiseptic preparation. This should produce enough irritation of the skin to cause a superficial hardening and desquamation. Sulphur, mercury and phenol preparations are used. Ichthyol in 5 to 15 per cent. ointment, resorcin in 2 to 10 per cent. ointment or any of the preparations used in acne are of service.

After the skin has peeled off, the underlying surface may be tender and inflamed, and require soothing applications such as boric acid solution or zinc oxid ointment. The second stage requires that the pustules be opened and evacuated as in acne. There still remain the dilated capillaries, which often amount to a telangiectasis. This is best cured by making multiple parallel incisions with a fine knife cutting through the vessels. The treatment of the third stage, that of hypertrophy, is entirely operative (see Rhinophyma, Vols. II and III). Prognosis good.

Pityriasis Rosea (with Rosy Patches Covered with Fine Scales).—The treatment should be conducted the same as that for eczema. Prognosis good.

Prurigo (a Chronic Disease, Beginning in Childhood, with Small, Pinkish Papules, with Infiltration of the Skin, and Itching).—The improvement of the general health is essential. Hot baths and alkaline baths, followed by oily applications are useful. Locally the following applications are used: betanaphthol (2 per cent. for children and 5 per cent. for adults), salicylic acid, tar, sulphur, phenol, balsam-of-Peru, borax, camphor, chloral, ichthyol, oil of cade and resorcin in ointments; any one of these medicaments in ointment form should be rubbed in at night. A prolonged bath in warm water should be taken every second day. The prognosis in severe cases is not good; the disease tends to persist. Symptoms can be much ameliorated.

Lepra (Leprosy).—Improvement of the general hygiene is important. Internally *chaulmoogra oil* and *gurjun oil* are used. The dose begins with 5 drops thrice daily, and is gradually increased. The treatment, as now used in the Philippines, is by injection. The following mixture is employed: chaulmoogra oil and camphorated oil 60 c.c. (2 ounces) each, and resorcin 4 Gm. (1 dram). These are mixed by the heat of a warm water bath and filtered. Injection is given once a week, beginning with 1 c.c. (15 minims). The dose is increased to the point of intolerance. This treatment seems to have cured some cases; it arrests the disease in most cases (V. G. Heiser: Am. Jour. Trop. Dis. and Prev. Med., Nov. 1914).

Recently *gynocardic acid* (*chaulmoogric acid*), the active principle of chaulmoogra oil, has been used. Sodium gynocardate is used for subcutaneous administration. The beginning dose is 0.006 Gm. ($\frac{1}{10}$ grain). The dose is increased by this amount at each injection. A 2 per cent. solution is used. The dose may be increased up to 0.048 Gm. ($\frac{4}{5}$ grain) before unpleasant effects are felt. More recently the drug has been used by intravenous injection. Locally antiseptic applications are used on the ulcerations. The ultimate prognosis is bad.

Molluscum Contagiosum (Characterized by Pink or White Pearl-like Elevations).—The general health should be improved. Each lesion should be incised, the contents removed, and the inside touched with caustic. It is easily curable.

Tuberculosis of the Skin.—(For the Constitutional and Local Treatment of Tuberculosis, see page 276.) The condition appears as *tuberculosis cutis, lupus vulgaris* and *tuberculosis verrucosa*. There are certain peculiar features in the treatment of tuberculosis of the skin, but the general principles are the same as the treatment of tuberculosis in other parts. Tuberculin seems to be of positive value in many cases. The bacillus emulsion (B.E.) should be begun in doses of $\frac{1}{50,000}$ mg. and increased 25 per cent. weekly. In ulcerated cases with mixed infection, staphylococcus vaccine is of value combined with tuberculin.

If the area is not too large the most effective treatment consists in the ablation of the disease. The infected area should be excised, and the wound allowed to granulate or it may be covered with skin. This is the treatment which should be applied to early lesions. Removal with the sharp curet is not so effective as excision. The cautery should not be used in the simple primary lesion. When there is doubt as to whether all of the disease has been removed some antiseptic, such as iodin or iodoform, may be applied. In many cases it is well to apply the antiseptic to prevent reinfection of the wound. The cautery is objectionable as it leaves much scar and interferes with the action of light rays. Cauterization should be reserved for old and complicated cases, not amenable to excision.

The Finsen light treatment of small areas gives most satisfactory results because healing takes place with the minimum of scar. A long time and especial skill are required to succeed with this treatment in large areas.

In cases in which the disease is superficial, the light alone will effect a cure. In cases in which the disease is deeper or in which there is old ulceration the *x*-ray should be used after the light has destroyed the superficial disease. In cases of extensive ulceration the light treatment may well be preceded by *x*-ray treatment (see Heliotherapy, Vol. III).

The *x*-ray in some cases cures the disease, but its action is not always beneficial (see *X*-ray, Vol. III).

Chemical cauterants are used with good result. Dermatologists recommend trichloracetic acid. A saturated solution is made by adding 10 drops of distilled water to 30 Gm. (1 ounce) of the pure crystals. A small swab, made by wrapping cotton around a wooden toothpick, is used to apply the solution to each congested nodule. The momentary pain may be relieved by applying an alkaline lotion. A pink powder may be applied to the skin to hide the white coloration. The application, at one time, should be made to areas not larger than 2.5 cm. (1 inch) in diameter. It should be repeated at the end of one or two weeks. Many applications must be made. The treatment requires several months.

The solid stick of silver nitrate, arsenical paste and other caustics are old and effective remedies, and may be applied so as not to destroy the healthy

skin (see Caustics, pages 73 and 330). A preparation much used for this purpose is composed of arsenic trioxid 1 part, red mercuric sulphid 2 parts, and ointment of rose water 24 parts. This is spread upon close-woven cloth and applied once daily for three days. Liquid air, pyrogallol (in 5 to 15 per cent. solution or ointment), radium and acid nitrate of mercury are all effective in this disease.

On mucous membranes excision or curettage is to be preferred just as in the skin, but where this can not be done the application of the following mixture is effective: Iodin 4 Gm., potassium iodid 8 Gm., and distilled water 8 Gm. Lupus of the palate may be painted one or more times daily with a mixture made of equal parts of resorcinol, balsam-of-Peru and mucilage.

The treatment applicable to most cases which are seen early in the disease is excision with the knife of the diseased area. The wound is then cauterized with pyrogallic acid, zinc chlorid, the actual cautery, or one of the other above-mentioned caustics, and allowed to heal by granulation.

The treatment, used successfully by Payr, consists in making two parallel incisions on either side of the disease down to the muscle. The bridge of affected skin is then lifted up, and a piece of iodoform gauze, soaked with balsam-of-Peru is drawn under the bridge. The same is applied to the surface. This dressing is changed every five days.

Sporotrichosis (a Mycotic Infection Due to the Sporothrix Schenkii).—This peculiar disease, which resembles both syphilis and tuberculosis, yields promptly to the local application of tincture of iodin and the internal administration of potassium iodid, 0.6 to 1.8 Gm. (10 to 30 grains) thrice daily.

Blastomycosis (with Wart-like Elevations Caused by Local Growth of Yeast Fungus).—The eradication of the parasite is not always easy. Extirpation of the diseased area, just as in tuberculosis, is advisable if it is not too extensive. All cases are improved by antiseptic applications. The *x*-rays and the local use of iodin and a 1 per cent. copper sulphate wash are the treatments now giving the best results in cases which are not excised. The internal administration of iodid of potassium, in the largest possible dosage, is of value.

Mycosis Fungoides (a Chronic Malignant Disease, Characterized by Erythema, Diffuse Infiltration and Red, Fungoid Tumors).—The only treatment that could be of avail is extirpation of the disease if recognized while localized. If not operable the ulcerations are to be dressed antiseptically. The disease usually ends in death.

Syphiloderma (Cutaneous Syphilitic Lesions).—The cutaneous lesions of syphilis require the constitutional treatment already described (see Syphilis, page 283). In addition to this the cure of the local manifestations can be hastened by the local use of mercury. Mercurial ointment is the best application which has the widest range of usefulness. The mercuric oleate ointment and mercurial plaster are also of service. Calomel is used as a dusting powder, and corrosive sublimate when a solution is required.

Tinea Favosa (Favus: a Contagious, Vegetable Parasitic Disease, Characterized by Dry, Yellowish, Cup-shaped Crusts).—The parasites causing this disease penetrate into the hair follicles, root sheaths and bulbs of the hairs. For this reason each hair in the diseased area must be pulled out to remove a constant source of infection. The adjacent hair should be kept closely cropped to reveal any new foci. The steps of the treatment are (1) the removal of the crusts with oil, soap and water, (2) epilation with forceps or spatula and fingers, and (3) the application of a parasiticide. The hair of

the diseased region must be pulled out hair-by-hair for a small area each day. This process may have to be repeated several times before the disease is cured. The application of a strong phenol solution lessens the pain of extraction of the hairs.

The scalp should be washed daily with green soap and hot water. After drying the scalp the antiseptic agent should be rubbed in. The curative agents are the same as for ringworm.

The most effective parasitic methods are the following: Dry the skin thoroughly and paint the affected area with tincture of iodin; or apply corrosive sublimate (1 : 1000 watery solution or 1 : 2000 alcoholic solution), phenol (5 per cent. solution or pure phenol followed by alcohol), or boric acid (saturated alcoholic solution). These applications must be repeated until crusts no longer form. Other parasiticides used are salicylic acid, sulphurous acid, chrysarobin, formaldehyd, ichthyol, naphthol, oil of cade and resorcinol.

Treatment by antiseptic ointments is slower but quite as effective. The milder applications should be rubbed in twice daily. The prognosis is favorable.

Tinea Trichophytina (Trichophytosis, Ringworm).—This parasite is easily destroyed. The crusts should be softened with oil, and removed with water and soap. Hair should be removed or cut short. After this the skin should be dried thoroughly either with alcohol or by exposure to dry heat. When the best possible dehydration with the least possible irritation has been secured tincture of iodin (diluted with equal parts alcohol for children) should be applied daily for three or four days. Other remedies are described, but this is sufficient. Any of the drugs used in favus may be used here.

In **tinea circinata** a mild parasiticide will effect a cure. Ointments of resorcin (6 to 12 per cent.) or ammoniated mercury (10 per cent.) are used. Corrosive sublimate (1 : 1000 in alcohol or 1 : 500 in water) is effective.

In trichophytosis of those parts of the body which lie in contact, such as the axilla, inner surfaces of the thighs and perineum, treatment is more difficult. The parts should be kept separated by a dry gauze dressing covered with bland powder, after the application of a parasiticide. Chrysarobin (2 per cent. in benzoinated lard) and tar ointment are useful applications.

Ringworm of the scalp (tinea tonsurans) requires that the hair shall be cut short over the whole scalp and the diseased area epilated. In tinea of the bearded portions of the face epilation should be practised. The *x*-ray in expert hands has given most excellent results. Success is secured by an exposure which is just sufficient to cause depilation—no less and no more. The rays are applied to the shaved head. **Tinea kerion** responds to the above treatments.

Prophylactic measures to prevent the spread of the disease to other persons should be taken. The prognosis is good.

Tinea Versicolor (Characterized by Irregular, Yellow or Fawn-colored, Scaly Patches).—Washing with soap and water prevents the disease and is the first step in its cure. Touching it with tincture of iodin suffices to destroy the vegetable parasites. Antiseptic lotions or ointments, described above, may be used. Washing with soap and water and applying a solution of hyposulphite of soda (15 or 25 per cent.) is an effective remedy. To prevent recurrence the underclothing should be boiled and a mild antiseptic applied to the skin for a time after the symptoms have subsided. The disease is easily cured, but recurrences are common.

Ringworm of the Scalp.—As this disease occurs commonly in children of school age the prevention of the spread of the contagion is most important. All exposed children should be examined, and the infected children should be isolated, as the spores of ringworm even in the dry state live for as long as eighteen months. The *x*-ray is the most satisfactory cure. Vaccine treatment has been found effective. If neither of these methods are used, the older treatments must be depended upon.

The parasites penetrate deeply into the hair follicles where neither chemical antiseptics nor *x*-rays will destroy them. Depilation is necessary for a cure. The hair should be cut short over the whole head for the sake of cleanliness. Crusts should be soaked and removed. One per cent. of beta-naphthol in olive oil is useful to soften crusts; then the head should be washed with soap and water.

Depilation is the most important part of the treatment. The hairs are best pulled out with forceps. This must be done over the whole diseased area, and repeated if necessary. The diseased area must be kept as completely depilated as possible, together with the immediately surrounding area. This is necessary in *x*-ray treatment also.

Antiseptics are especially useful in preventing the spread of the disease. The affected area should be painted daily with 2 per cent. alcoholic solution of iodin and the rest of the scalp should be treated with a mercurial ointment such as is described above. Every other day the head should be washed with soap and water. Other remedies are chloraminated oil, phenol (10 per cent. in glycerin), oleate of mercury (10 to 20 per cent. ointment) and mercuric chloride (1 : 1000).

The disease requires fully two years of faithful treatment for its cure. Care should be taken not to pronounce a case cured before it is cured. The case should be watched for six months after a cure is supposed to have been accomplished.

The *vaccine treatment* of ringworm is giving most gratifying results. A stock vaccine is usually used. Rarely is an autogenous vaccine necessary. The disease should be controlled by cultural tests of the infected hair. No local treatment is necessary. An injection is given once every five days. Five injections usually suffice. The beginning dose is 0.5 c.c.; 1 c.c. for the second and third doses; and 2 c.c. for the fourth and fifth.

HYPERTROPHIC SKIN DISEASES

Lentigo (Freckles).—Solution of bichlorid of mercury, in strength varying from 1 : 1000 to 1 : 100 in water or alcohol is useful. This should be touched to the freckles two or three times daily until a mild desquamation ensues. Milder applications are: borax ointment; mercuric acetate (1 : 300); lactic acid; compound tincture of benzoin (1 part in 7 parts of water); hydrogen peroxid (effect temporary); lime water; and resorcinol (0.60 to 1.30 Gm. in 30 c.c. of water or 10 per cent. ointment). The following ointment is also employed: Hydrargyri ammoniati 4 Gm., bismuth subnitratis 4 Gm., glyceriti amyli 30 Gm. The disease is not easily curable, nor need it be.

Chloasma (Liver Spots; Yellowish to Blackish; Varying in Shape).—Constitutional derangements should be corrected. Locally the same measures that are used for lentigo (freckles) are employed. Too much irritation or blistering of the skin may make the condition worse. Painting the skin with phenol, to cause it to exfoliate, seems effective in some cases. The most useful applications are corrosive sublimate, lactic acid, salicylic acid

and hydrogen peroxide. Bulkley recommends the following lotion to be applied twice daily: Hydrargyri chloridi corrosivi 0.3 Gm. (5 grains), acidi acetici diluti 8 Gm. (2 drams), sodii biboratis 2.50 Gm. (40 grains), aquæ rosæ 120 c.c. (4 ounces). The prognosis is variable.

Keratosis Pilaris (Characterized by Pinhead, Conical Elevations about the Follicles).—A cure is usually effected by the continued use of baths with water and soap. If the skin is dry oil should be rubbed in. A mild salicylated ointment may rarely be indicated.

Lupus Erythematosus (Characterized by Slightly Elevated, Round Patches, Covered with Yellowish Gray Scales, and Ending in Atrophic Scarring).—The general condition of the patient should be given special consideration. This is one of the most difficult of skin diseases to cure. The treatment is similar to that of eczema. If there is inflammation, the applications should be soothing. Leadwater and zinc oxid ointment are used.

In the early stage of congestion soothing applications are best. A good preparation is calamin 1 part, zinc oxid 3 parts, glycerin 4 parts and lime water 30 parts. Another soothing lotion consists of zinc sulphate 1 part, potassium sulphuret 1 part, resorcin 1 part and rose water 30 parts.

In the more chronic conditions, a 25 per cent. solution of resorcin, applied repeatedly to cause frequent exfoliation of epidermis, sometimes causes improvement. After the acute stage has passed the circumference of the diseased area may be cureted, and the wound treated with tincture of iodin.

Liquid air and carbonic acid snow, as used in nevus, have given good results in many cases.

Radium has given more uniform success in this disease than any other local treatment (see Radiotherapy, Vol. III). The *x*-ray and thermoradiotherapy are also effective. These measures seem to give the best results when administered in dosage strong enough to cause destruction of tissue and cicatrization.

In the chronic stages, stimulating applications are called for. Tincture of green soap, followed by resorcin, tar, pyrogallic acid, or ichthyol ointment, is used. If the milder stimulants fail, more active agents, such as tincture of iodin, phenol and alcohol, or scarification, are employed. Often the disease is quite intractable; and in these cases the more vigorous methods are called for.

Callositas (Callus: Hard Skin).—The essential of treatment is the removal of the cause. The hardened skin may be treated by soaking in hot water and soap and scraping it off. Salicylic acid (8 to 20 per cent.) in ointment, collodion, solution or plaster will soften the callus. Ichthyol and lead ointment are also used.

Clavus (Corn).—The prevention and treatment are the same as for callus (see above). Maceration with salicylic acid and scraping off the corn is the most satisfactory. When a corn becomes infected, it must be treated the same as cellulitis (see Wound Infection, page 228 and Cellulitis, page 237. See also Ulceration, page 308).

Horn (Cornu Cutaneum).—The treatment is excision, as with any tumor. Unless the base is all removed, recurrence may take place.

Verruca (Wart).—The treatment consists in dealing with the wart as a tumor, and removing it by excision or caustic. The common warts of the hands are best treated by a caustic carefully touched to the disease but not to the healthy skin. For this purpose may be used glacial acetic acid, chromic acid (25 per cent. solution), nitric acid, sulphuric acid or phosphoric acid. The following is effective: acidi salicylici 2 Gm., extracti

cannabis indicæ 0.3 Gm. and collodii 15 to 30. Gm. Another useful formula substitutes resorcinol for the cannabis indica. All of these require to be repeated once or twice a week until a cure is effected. Ethyl chlorid destroys warts. The wart should be surrounded by a ring of cotton, wet with cold water, about 1 cm. beyond the wart. Ethyl chlorid is sprayed on the wart until it is frozen. The adjacent skin must not be frozen. If one application does not cure, it may be repeated in ten days. A useful combination is 10 parts sulphur, 5 parts concentrated acetic acid, and 4 parts glycerin. This is applied daily till the wart drops off.

Larger warts, such as the *verruca plana*, are best treated by freezing with ethyl chlorid and then curetting away the growth. The wound is painted with pure phenol and dressed with a mild antiseptic powder.

Nevus Pigmentosus (Mole).—The most effective treatment is refrigeration by means of solid carbon dioxid. The treatment causes but little pain and leaves only a slight scar. The liquid gas is a common article of commerce. It may be obtained in drums or cylinders from manufacturers of

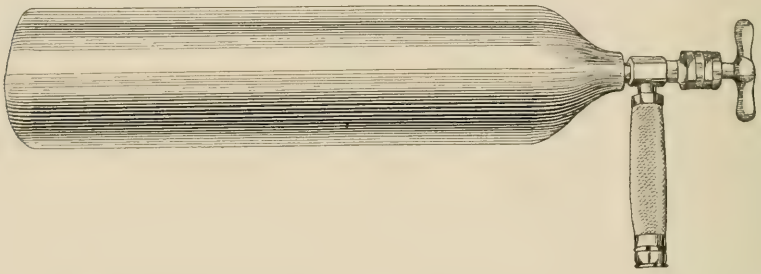


Fig. 652.—Apparatus for Containing Compressed Carbon Dioxid with Attachment for Delivering Solidified and Compressed Crayons of CO_2.

carbonated waters. The cylinder should be placed so that the outlet is at the bottom. A piece of chamois skin is tied at the nozzle to make a bag to receive the fluid; or it may be received into a mould which shapes the snow into the form of a pencil (Fig. 652). The stick of snow may be sharpened like a crayon. In flat, pigmented and hairy nevi the snow should be applied for thirty seconds in children and women with delicate skin. Persons with coarse skin may require an application of a minute or longer. In lesions not larger than 1.25 cm. (½ inch) in diameter, one treatment suffices. Larger lesions require more than one treatment. The application causes a burning sensation. Blisters soon appear, and a destruction of the superficial tissues is evident. Vascular, papillomatous and thickened nevi require several treatments of one-half to three-quarters of a minute each.

Port wine stains yield to radium treatment (see Radiotherapy, Vol. III).

The growths may be removed by the caustics used for warts (see above). Larger moles, especially of the hairy variety, are best removed by excision with the knife. Removal of all moles, especially of the extremities and places where they are exposed to irritation, is wise treatment because of their tendency to undergo malignant degeneration.

Ichthyosis (Chronic Congenital Hypertrophy with Dryness and Scaliness).—Treatment can give temporary palliation of symptoms. It is directed toward softening and removing the scales. Hot baths, preferably in alkaline water, with soap, are to be followed by rubbing with oil or vaselin. Applications may be made of salicylic ointment, borax, ichthyol, naphthol

(5 per cent. ointment) or resorcinol (3 to 15 per cent. ointment). The disease is not cured.

Scleroderma (Induration of the Skin, usually Pigmented and Followed by Atrophy).—Hot applications to improve the circulation, massage, electricity, vibration and ointments are of service. A stimulating oil is useful in many cases; 1 or 2 parts oil of turpentine with 6 parts of olive oil. Many cases are rebellious to treatment.

ATROPHIC SKIN DISEASES

Ainhum (Observed Usually in the Toes of the Negro).—When the disease is recognized early, the treatment consists in excision of the atrophic band surrounding the digit. Later, when the circulation has been destroyed, amputation of the toe should be done.

Leukoderma (White Skin; Patchy Atrophy of the Skin Pigment).—The white patches may be excited to pigment production by the induction of hyperemia. This may be done by suction, blisters, galvanism or irritating applications. The spots may be tattooed with a dye which matches the surrounding skin, or temporarily stained with walnut juice or weak iodin solution. Arsenic internally has in some instances been followed by improvement. The same local remedies as used in chloasma and lentigo may be applied to the surrounding excessively pigmented skin.

NEW GROWTHS OF THE SKIN

Cicatrices and keloid are dealt with elsewhere (see Results of Wounds, page 225). Fibroma, myoma, neuroma, lipoma, epithelioma and sarcoma are discussed under Tumors (see page 323). Neuroma, angioma and lymphangioma are considered under the special structures from which they spring. Rhinoscleroma and Paget's disease will be found in the chapters dealing respectively with the face and breast. **Xanthoma** is to be treated by excision. **Keloid** yields to *x*-ray treatment (see Vol. III).

NEUROSES OF THE SKIN

The neuroses such as hyperesthesia, dermatalgia and anesthesia are symptoms of nerve disturbances. Treatment demands discovery of the cause. In dermatalgia, local pressure sometimes gives relief.

Pruritus (Itching without Cutaneous Lesions Excepting such as are Caused by Scratching).—Removal of the cause is the important step in the treatment. The constitutional or local defect should be found and remedied. Local applications are capable of giving much relief. Hot alkaline baths are useful. Menthol (2 per cent.), phenol (2 to 3 per cent.), cyanid of potassium (1 : 500), chloroform, vinegar, alcohol, liquor picis alkalinus (2 to 3 per cent.), or calomel powder are used with good effect.

In cases in which the skin is dry, ointments are best. Phenol 1 Gm., in zinc oxid ointment 30 Gm., is useful. Phenol may be applied in strong solution and neutralized with alcohol. Other antipruritics are menthol, camphor, chloral, thymol and oil of cade. Phenol may be used in 3 to 10 per cent. solution; menthol in ¼ to 1 per cent. solution or 2 per cent. ointment; camphor may be mixed with equal parts of chloral, and painted on; thymol in 2 per cent. solution; and oil of cade in 10 per cent. ointment. Tincture of iodin may be used in glycerin.

Water as hot as it can be borne often is of service in *pruritus of the anus* and *genitals*. Calomel ointment is also useful. Extreme cleanliness will cure many cases. Discharges and local disease must be cured. For pruritus of the genitals strong solutions of alum are often of service; also corrosive

sublimate (1:2000). Brewer's yeast or baker's yeast applied in water will often cure difficult cases. Silver nitrate in strong solution or pure cures many cases. The high-frequency current sometimes helps. Some cases respond to *x*-ray. Pruritus of mucous membranes may be temporarily relieved by the application of cocain, adrenalin or morphin.

Ligation of the artery to the part, division of the nerve or nerves, injection of the nerve trunk with alcohol, and excision of the pruritic skin are all procedures which have proved successful when everything else has failed. The prognosis is usually good; in some cases the disease is obstinate; in old persons it is often incurable.

Lumbar puncture and withdrawal of 3 to 6 c.c. (45 to 90 minims) of cerebrospinal fluid has cured rebellious cases.

DISEASES OF THE GLANDS OF THE SKIN

Hyperidrosis (Excessive Sweating).—General treatment to improve the general health is important. Locally the use of astringent lotions is of service. Bathing the skin with a 1 per cent. solution of quinin is effective in some cases. Extract of pinus canadensis is used for the feet. Solutions of tannin (1 to 2 per cent.) or alum (0.4 per cent., 2 grains to the ounce), or formaldehyd (1 per cent.) are effective. Lead and zinc salts also are used. These lotions should be followed by a dusting powder, such as starch or boracic acid, combined with 2 to 5 per cent. of salicylic acid. Sweating feet may be treated with the above astringent solutions or a 3 to 5 per cent. solution of chromic acid. Diachylon ointment also is of service, followed by powder. Tannoform (10 per cent.) in starch is efficacious. A 25 per cent. solution of aluminum chlorid in distilled water painted on the parts every second day and allowed to dry is recommended by A. W. Stillians. A 2 per cent. solution of liquor formaldehyd in water may be applied to the axillæ and a 5 per cent. solution to the feet.

Anidrosis (Dry Skin).—Besides the correction of constitutional derangements, the free drinking of liquids, the local use of heat and cold, hot water baths, vapor baths, massage, etc., to stimulate the skin are used. Oils and ointments may be rubbed in the skin.

Bromidrosis (Abnormal Odor, usually with Hyperidrosis).—Care of the health is important. Bathing the skin with soap and water, the application of astringent lotions if there is hyperidrosis, and dusting powders containing borax or salicylic acid (2 to 10 per cent.) are the routine treatment. A 1 per cent. alcoholic solution of formalin, or a 1 per cent. solution of potassium permanganate may be used. A 5 or 10 per cent. solution of chromic acid may be painted on once every month. Bromidrosis and hyperidrosis of the feet are benefited by painting the parts with 10 to 30 per cent. solution of formalin or with 8 per cent. solution of silver nitrate. A 10 per cent. powder of salicylic acid or tannoform should be dusted in the stockings. Fissures should be treated with ointment.

Miliaria (Prickly Heat; an Acute Inflammation of Sweat-Glands, with Vesicles and Papules).—Remove exciting cause. Keep skin cool and clean. Alkaline lotions, such as bicarbonate of soda (5 to 10 per cent. solution), followed by mild antiseptic dusting powders (zinc oxide, or borax and starch) constitute the treatment.

Seborrhea (Excessive Secretion of Sebum).—General attention to the personal hygiene is essential. In seborrhea of the scalp (dandruff), shampooing with water, soap and a brush is the first step in local treatment. Where the crusts are hard and dry they must first be softened with oil or ointment. Preferably the hair should be cut short although it is not essential. The

shampoo should be repeated every second or third day, until the scalp is clean. Then one of the following ointments or lotions should be rubbed in the scalp daily:

Resorcin 1.3 to 4 Gm. (20 to 60 grains) in cold cream, 30 Gm. (1 ounce).

Resorcin 4 to 8 Gm. (1 to 2 drams), olei ricini 4 Gm. (1 dram), alcoholis 150 c.c. (5 ounces).

Hydrargyri chloridi corrosivi 0.03 Gm. (½ grain), chlorali hydrati 15 Gm. (4 drams), resorcinolis 8 Gm. (2 drams), spiriti myrciæ 120 c.c. (4 ounces), aquæ, quantum sufficit, ad 200 c.c. (7 ounces).

Hydrarg. ammoniat. 2 Gm. (30 grains), ung. rosæ 30 Gm. (1 ounce).

Acidi salicylici 1 Gm. (15 grains), sulphuris precipitati 4 Gm. (1 dram), petrolati mollis 30 Gm. (1 ounce).

Phenolis 4 Gm. (1 dram), olei amygdalæ 30 c.c. (1 ounce), olei limonis 8 c.c. (2 drams), aquæ, ad 120 c.c. (4 ounces).

Other preparations are resorcinol (1 to 10 per cent. lotion or alcoholic solution or 5 or 10 per cent. ointment), salicylic acid (2 to 5 per cent. ointment), phenol (2 to 3 per cent. solution or ointment).

Seborrhea oleosa should be treated with astringent antiseptic lotions and dusting powders such as are used in hyperidrosis. The disease can usually be cured. Some cases are obstinate. The tendency to recurrence is strong.

Comedo (Blackheads; due to Clogging of Sebaceous Follicles).—The general health should be bettered. The tone and cleanliness of the skin should be improved by washing with warm water and soap, to be followed by the application of water as hot as can be borne, this is to be followed by a cold douche. The retained sebum should be squeezed out of the distended glands. This may be done with the fingers or with some small circle, like the end of a hollow key, which will make pressure around the follicle. A comedo extractor is made for this purpose (Fig. 653). The vacuum suction cup is highly useful both for emptying the follicles and stimulating the circulation. Antiseptic stimulating applications are efficacious. The following are used: resorcinol (5 per cent. solution or ointment); zinc oxid ointment, containing 5 per cent. ichthyol; borax powder or calomel and stearate of zinc, equal quantities. The following lotion is effective: zinc sulphate (4 parts), sulphurated potash (4 parts), in rose water (120 parts). The same remedies that are used in acne are applicable.

FIG. 653.—COMEDO EXTRACTOR.

Milium.—Incision of the milium and evacuation of the sebaceous contents are necessary. To prevent recurrence, the sac should be removed or its epithelial lining destroyed with caustic.

Steatoma (Sebaceous Cyst, Wen.).—The treatment of this disease consists in dissecting out the whole cyst wall. Usually a local anesthetic is best. Not only the skin surrounding the tumor should be anesthetized but also the connective tissue upon which the tumor rests. An elliptic incision is made over the middle of the tumor. The ellipse of skin is left attached to the sac, and the surrounding skin is dissected free. The skin being retracted, the cyst is dissected out without rupturing it. If it is ruptured in the course

of the dissection, pains should be taken that all of the sac is removed (see Cystomata, page 325).

DISEASES OF THE HAIR AND NAILS

Hypertrichosis (Superfluous Hair).—In cases in which the condition is extensive, treatment is not advisable. The use of depilatory drugs is not to be recommended as their action does not prevent the growth of the hair. When necessary such a depilatory may be made as follows: Two parts of slaked lime and 3 parts of water are mixed. Into this mixture hydrogen sulphid is passed as long as it is absorbed. This preparation is to be well mixed before using. An application for eight or ten minutes, washed off with water, removes the hair. A strong solution of calx sulphurata may be used for the same purpose.

The scientific removal of superfluous hair is accomplished by electrolysis. The skin should be cleaned. A fine needle is connected with the negative pole of a galvanic battery. The positive pole is connected to a moistened sponge placed against the skin. The needle is passed down along each hair to the bottom of the hair follicle. That is from 2 to 7 mm. ($\frac{1}{16}$ to $\frac{1}{4}$ inch). The current is then turned on until frothing and blanching is observed at the mouth of the follicle. This should require from ten to thirty seconds. The needle is then removed, and the loosened hair extracted. A current of 1 or 2 milliampères is employed. It is best not to operate upon contiguous hairs at one sitting. From 10 to 50 may be removed at a time. Soothing applications should be used; and reaction should have subsided before the next treatment is applied to the same region.

Alopecia (Baldness).—Congenital and senile alopecia are not amenable to local treatment. Syphilitic disease requires antisyphilitic treatment. Premature baldness in healthy persons can be ameliorated. Persons having a hereditary tendency to baldness may save their hair by giving attention to the hygiene of the scalp and to the general health. The habit of deep breathing, particularly complete expiration, to drain the lungs of residual air, is important. Life in the fresh air, keeping the scalp clean, abstinence from headwear that hinders the blood-supply to the scalp, and avoidance of the violations of hygiene which conduce to obesity, are among the essentials of prophylaxis.

When the loss of hair has begun, the scalp should be given an unirritating shampoo every week or two. Stimulating applications, aimed to induce a slight hyperemia should be applied. The following are some of the preparations used:

Hydrarg. chlorid. corrosiv. 0.25 Gm. (4 grains), euresol 10 Gm. ($\frac{1}{3}$ ounce), liquor formaldehydi 10 c.c., ol. ricini 8 Gm. (2 drams), alcohol (70 per cent.) 240 c.c. (8 ounces). Rub in two teaspoonfuls in the morning.

Sulphur præcip. 4 to 8 Gm. (1 to 2 drams), betanaphthol 2 to 4 Gm. ($\frac{1}{2}$ to 1 dram), lanolin 8 Gm. (2 drams) and vaselin enough to make 30 Gm. (1 ounce).

Hydrargyri chloridi corrosivi 0.2 Gm. (3 grains), tincturæ cantharidis 15 c.c. ($\frac{1}{2}$ ounce), olei amygdalæ dulcis 4 c.c. (1 dram), spiriti rosmarini 30 c.c. (1 ounce), alcoholis 60 c.c. (2 ounces), aquæ destillatæ *q.s.* ad 180 c.c (6 ounces). To be rubbed in the scalp once daily.

Phenolis 1 Gm. (15 grains), glycerini 8 c.c. (2 drams), aquæ rosæ 30 c.c. (1 ounce). To be rubbed in the scalp once daily.

Chrysarobin 0.65 to 4 Gm. (10 to 60 grains), lanolin 30 Gm. (1 ounce).

Resorcinolis 4 Gm. (1 dram), olei ricini 30 c.c. (1 ounce), alcoholis 120 c.c. (4 ounces), olei gaultheriæ 1 c.c. (15 minims). Rub in daily.

Tincturi capsici 15 c.c. (½ ounce), olei ricini 4 c.c. (1 dram), aquæ rosæ 30 c.c. (1 ounce). Apply daily.

Tincturi cantharidis 15 c.c. (½ ounce), olei ricini 4 c.c. (1 dram), aquæ menthæ piperitæ 30 c.c. (1 ounce). Apply daily.

Mechanical treatment is also of value. Massage of the scalp may be applied either alone or in connection with some of the above medications. The use of the suction principle of hyperemia is one of the effective modes of treatment.

The treatment of *alopecia areata* should be according to the above principles. Painting the area with trikresol is effective in some cases. Besides stimulating applications, it is found that antiseptics have a decided value in many cases. An effective treatment consists in painting the area with tincture of iodin. Pure phenol, followed with alcohol, is also useful. Parasitic ointments are employed. In young adults the prognosis is good.

Alopecia Follicularis (an Inflammation Involving the Hair Follicles, Destroying the Papillæ and Leaving Permanently Scarred and Bald Patches).—Its progress may be checked by tincture of iodin, or strong bichloride of mercury solution.

Sycosis (a Chronic Inflammation of Hair Follicles of the Face, Causing Papules and Pustules).—The general health should be improved. Crusts should be removed with oil, warm water and soap. If there is much irritation, soothing applications should be used. The hair should be cut short at first, and then when the acute inflammation has subsided it should be shaved every second day. Pustules should be incised. Antiseptic ointments or lotions are effective.

In inflamed cases, saturated boracic solution, or resorcin (¼ to 1 per cent.) solution, may be applied, and followed by a mild ointment. Later a 2 or 5 per cent. sulphur ointment may be used. In chronic cases stimulating applications are best. Ichthyol ointment (5 to 10 per cent.) or salicylic acid (2 to 10 per cent. ointment) is used. Kaposi recommended the following: betanaphthol 1 Gm. (15 grains), soap liniment 24 c.c. (6 drams), alcohol 45 c.c. (1½ ounces), balsam of Peru 2 c.c. (½ dram), sulphur 10 Gm. (2½ drams). Stelwagon recommended sulphur præcip. 4 Gm. (1 dram), balsam of Peru 4 Gm. (1 dram), and ung. diachyli 24 Gm. (6 drams).

Jackson used the following: red sulphid of mercury 0.45 Gm. (7 grams), sulphur 12 Gm. (3 drams), lard 45 Gm. (1½ ounces), oil of bergamot, enough to make an ointment.

The disease is distinctly curable.

Atrophia Pilorum Propria (Atrophy of the Hair).—If due to some disease which interferes with the nourishment of the hair, the causative factor should receive attention. Fragility of the hair and *trichorrhexes nodosa* require cutting or shaving of the hair, and treatment of the scalp to improve the health of the skin.

Injuries of Nails.—Contusions of nails sometimes result in the formation of *subungual hematoma*. Usually these require no treatment. If a subungual abscess develops, the overlying nail should be cut away. Fractures of nail caused by contusions, should be treated by pressing back the nail into normal position and holding it with a dressing. Any part of the nail that is detached from its matrix should be cut away. Wounds exposing the matrix should be dressed with ointment and oiled silk, rubber, or other non-porous covering, because of the pain caused by the removal of adherent material. When there is a partial avulsion of the nail, the loose part should be cut off. If the matrix is not destroyed new nail will grow (see Fingers, Vol. III).

Onychauxis (Hypertrophy of Nail).—Any local or constitutional disease which may be an etiologic factor should be removed. Excessive nail may be softened by warm poultices and cut away. If paronychia is present pieces of gauze and antiseptic powder should be packed between the nail and the inflamed tissues.

Onychia (Onychitis, Inflammation of Nail).—Incision through the nail is required to relieve the tension of inflammatory products. Often the whole nail must be removed.

Onychia Maligna (Tuberculosis about the Nail).—This condition requires the treatment described for tuberculosis of the skin.

Perionychia.—The treatment is that of local inflammation or cellulitis: hyperemia by mechanical means, wet antiseptic applications and incision for suppuration.

Tylosis (Callosity of the Matrix).—The nail should be split or extracted and the callosity removed.

Paronychia (Infective Inflammation under the Skin around the Nail).—The treatment should be the same as for cellulitis: hyperemia by mechanical means, wet antiseptic applications (bichloride solution 1 : 1000), and free incision as soon as pus appears. Dead skin should be kept trimmed away. When pus appears under the nail, all of the nail that is loosened from its matrix should be cut away (see Phalanges, Vol. III).

Atrophy of Nails.—Systemic or local causative disturbances should be treated. If the disease is due to fungi (onychomycosis), the nail should be scraped or macerated to soften it, and a parasiticide applied.

ANIMAL PARASITES OF THE SKIN

Scabies (Itch, due to the Acarus Scabiei).—If much inflammation is present, soothing applications should first be used. The parasites may be destroyed by betanaphthol (10 to 15 per cent. ointment), balsam of Peru, benzin, resorcinol (5 to 10 per cent. ointment), turpentine, or sulphur. The latter is much used in the form of sulphur ointment. For children, 10 per cent. of balsam of Peru may be added to the sulphur ointment.

A useful ointment to rub into the diseased area is made of 1 part creolin to 10 parts benzoinated lard.

Prophylaxis requires the simultaneous treatment of all contiguous cases and the disinfection of infected clothing. The disease is easily curable.

Pediculosis (Lousiness).—Pediculosis of the head is cured by destroying the lice (Pediculus capitus) by an application of kerosene oil for twenty-four hours. The oil should be removed with soap and water. Other applications used are corrosive sublimate solution (1 : 500), phenol (2 to 3 per cent. solution), balsam of Peru, and the antiseptic ointments. It is rarely necessary to cut the hair.

The body louse (Pediculus corporis) is treated by steaming, boiling or baking the clothing in which it lives. The crab louse (Pediculus pubis) is killed by applying to the skin solutions of bichlorid of mercury (1 : 500), or phenol (1 : 30); or by equal parts of kerosene and balsam of Peru, resorcinol ointment (5 to 10 per cent.), or betanaphthol (10 to 15 per cent. ointment). The lotions are cleaner.

Cysticercus Cutis.—The scolex of the tapeworm in the skin, forming a little tumor the size of a pea or cherry, is treated by incision and evacuation.

Trombidiosis.—The red jigger (Trombidium irritans, harvest bug, mowers' mite) which buries the anterior half of its body in the skin, can be washed off before it has become attached; but after becoming fixed it is best removed with a needle. The parasite should be destroyed at once and the

spot touched with tincture of iodin. If the jiggers cannot be removed with a needle, the area may be painted with tincture of iodin daily, and in the course of a week the parasites will die.

REMOVAL OF TATTOO MARKS

The method of Brault consists in cleansing the skin, tattooing the region with a 75 per cent. solution of zinc chlorid by dipping the tattooing needle in this solution. The skin is then moistened with the solution, and allowed to dry. This sets up an inflammation in the skin which forms a crust. The crust falls off in about a week, leaving a very slight scar. If the tattooing is carried too deeply or is not aseptically done deep suppuration and bad scarring results. If the operation is too superficial, it fails.

A method which gives possibly better results is that of Variot. The skin is cleansed, and a 25 or 50 per cent. solution of tannic acid is painted on the tattoo marks. This is tattooed in. A stick of silver nitrate is then rubbed on the skin until it is black with silver tannate which is formed in the skin. The surface is then washed with water. A crust forms which comes off after two weeks. A thin pink layer of skin appears under the crust. In the course of a few months this becomes paler and leaves a scarcely noticeable scar.

COSMETICS

Remedies for the treatment of the common skin diseases are described above; but there are slight lesions which require treatment largely for cosmetic reasons. Simple irritations of the skin and blemishes often require some simple emollient or astringent.

For supplying oil to a dry skin the following *cold cream* is useful: mix and melt together 200 Gm. white petrolatum, 15 Gm. white paraffin, and 60 Gm. anhydrous lanolin. To this warmed fluid mixture add gradually 90 c.c. lukewarm water and 4 c.c. alcohol, and mix into a light creamy mass with an egg-beater. After the mass has cooled add 3 drops of oil of rose or other perfume. An antiseptic value may be added by mixing in 5 or 10 Gm. of borax which is dissolved in water before it is added.

For **perspiring hands** the following is useful: 125 rose water, 10 borax, and 8 glycerin. In more aggravated cases the hands should be dipped alternately into very hot and very cold water for five minutes and then rubbed with 10 per cent. tannin in glycerin.

A lotion for **chapped hands** is the following; 8 glycerin, 4 bay rum, 4 ammonia water, and 4 rose water, added in the order named and then well shaken. Another mixture is 90 bay rum, 30 glycerin, and 2 phenol.

For the treatment of **blackheads** the following is recommended: 1 thymol, 2 boric acid, 18 distilled extract of witch hazel, and rose water enough to make 200. The face should first be washed with hot water and soap and rubbed with a coarse towel twice daily, and the above lotion applied.

An emollient made without grease which is used as a *face cream* is the following: 10 Gm. of quince seed are macerated and stirred in 500 c.c. of boiling water for two hours and a half, and then strained. To 500 c.c. of boiling water add 5 Gm. borax and 5 Gm. boracic acid, and when cool add 100 c.c. glycerin and 125 c.c. alcohol. If perfume is desired attar of roses may be added to the alcohol. Then add slowly the cooled quince seed mucilage, shaking all the time.

AUTOSERUM TREATMENT OF SKIN DISEASES

This treatment is especially useful in psoriasis, but it is useful also in various forms of obstinate chronic eczema, in chronic urticaria and in pustular acne (for Technic, see Psoriasis, page 835).

NERVES

The satisfactory treatment of injuries and diseases of nerves demands an understanding of the peculiar anatomy, physiology and pathology of these highly specialized structures. The axis cylinder is the essential part of the nerve fiber. It is continuous from the central cell, of which the nerve is a projection, to the terminal organ or peripheral enlargement of the nerve. Conductivity requires that this structure shall be intact and continuous. Its division or compression interrupts the passage of impulses. Compression is most commonly the result of the deposit of inflammatory tissue, the contraction of which shuts off conductivity.

When nerve fibers are severed, degeneration of all that part of the nerve beyond the point of severance takes place. Even though the nerve is immediately and successfully sutured, this phenomenon occurs. Regeneration of a restored nerve takes place from the central axon outward or by union of a new peripheral axon with the proximal axon. So long as some axis cylinder remains, regeneration may be expected to take place after continuity is restored; and muscles which are supplied by such nerves may have their power restored if the muscle fibers have not too far degenerated and become replaced by fibrous tissue. Thus it is important to keep up to the best possible condition the nourishment and local health of paralyzed nerves and muscles. This is done by attention to the general health of the patient, and locally by massage, passive motion, and electricity.

Whether the degeneration follows circumscribed inflammation, tumor, hemorrhage, compressing bone or foreign body or traumatic division of the nerve, the cause should be removed if possible. In doing this, if a segment of hopelessly injured nerve is removed, bridging of the gap must be accomplished by some of the methods which will be described. If the nerve has simply been divided by traumatism, it should be united at once. When immediate suture is not practised, the gap between the divided ends becomes filled with scar tissue through which new axis cylinder material can grow only with difficulty. The operation of secondary nerve suture requires the freeing of the ends from this scar tissue and their reunion, either directly or by plastic operation.

There may be *difficulty in identifying a nerve*. This may be overcome by the use of electricity. One pole of a battery may be connected with the dissecting scalpel, and the muscular response when the nerve is touched observed.

The length of *time required for a nerve to regain its function* after being reunited is variable. At least two months elapses before the return of function after primary suture. After secondary suture, return of function has been observed within a few hours; usually a longer time is required. In all cases, from six to twelve months should be allowed for the full restoration of function.

After the paralysis of an efferent nerve, the paralyzed muscle should be placed in a position of relaxation. The opposing muscles should not be permitted to stretch it. Its nutrition should be maintained by massage and passive motion.

All operable nerves, which have been injured and which give the reaction of degeneration after the tenth day, should be operated upon. Suture will usually be found necessary.

CONTUSIONS OF NERVES

Contusions which produce symptoms must be regarded the same as wounds, nerve fibers are divided, split apart and compressed. In severe contusions there is the disadvantage that it is difficult to determine whether the nerve is damaged sufficiently to recover without suture or not. If the paralysis disappears after a few days or from the beginning is not complete, it may be assumed that the nerve is not seriously damaged. The presence of reaction of degeneration is an evidence of serious injury, but it cannot be determined whether function will be restored spontaneously until time is given for regeneration. If the reaction of degeneration persists after ten days, restoration of function without operation is not to be expected.

In all cases the parts should be kept at rest to minimize the amount of exudate. Cooling applications, a splint and a firm bandage are of service. The parts should be immobilized in the position that will give the most relaxation to the nerve. An analgesic may be required. To hasten the absorption of exudate, hot applications and massage should be used.

If the nerve has been completely divided as can sometimes be discovered by feeling in the case of some of the larger nerves, it should be exposed and sutured at once. If paralysis persists beyond the period within which regeneration should take place the nerve should be exposed, cleared of scar tissue, and, if necessary, sutured. When such operations are done, it is often discovered that instead of waiting it would have been better to have operated earlier, as the operation reveals a condition which could not have healed spontaneously. This gives rise to the wisdom and justification of exposing the nerve in doubtful cases to determine by the eye, rather than by the lapse of time, whether a nerve suture or other operation should be done.

COMPRESSION OF NERVES

Temporary compression of nerves, caused by faulty positions, crutch pressure or the defective use of bandages or splints, is overcome by the removal of the cause. Compression by scar tissue or inflammatory products is not always permanent, and often under treatment of the inflammation the compressing exudate disappears and the nerve resumes its function. In other cases the deposit is more dense but can be made to release the nerve through treatment with hot applications, heat and cold alternately, massage, vibrations or electricity. In chronic cases or when these methods have failed, the nerve should be exposed and dissected free from the compressing tissue (*neurolysis*). In performing this operation, it is best to expose the normal nerve first on either side of the compression. It should then be liberated, care being taken not to injure it, and the surrounding scar tissue removed. By slightly stretching the damaged part of the nerve, the restoration of function is hastened. In large nerves, the sheath may be found thickened; this should be divided longitudinally to relieve still more the compression. Perfect asepsis and the minimum amount of traumatism to the tissues should be depended upon to prevent the reforming of scar. If possible, muscle, unirritated fascia or other normal tissue should be caused to line the bed in which the nerve lies. A wrapping of fascia may be employed for this purpose.

OPERATIONS ON NERVES

In operating on large mixed nerves, the surgeon should bear in mind that they should not be thought of as nerve units, but rather as bundles of separate nerves. Thus in the case of a nerve like the sciatic, it is possible to isolate these several constituent nerves. A. Stoffel (Mediz. Klinik, Aug. 31, 1913) showed that by marking out on the body the areas of pain, by touching bundles with an electric current and by studying the muscular reactions, it is possible with gentleness to separate the constituent nerves (Fig. 654). A needle electrode, touched to a nerve fasciculus, causes pain or muscular contraction, which serve as the guide. Fasciculi may be released from pressure and motion restored. Sensory bundles may be divided for neuralgia. By separating the sensory from the motor bundles, surgical attention may be given to the specific nerve that is affected without disturbing all the other nerves in the bundle as has been the common and crude practice.

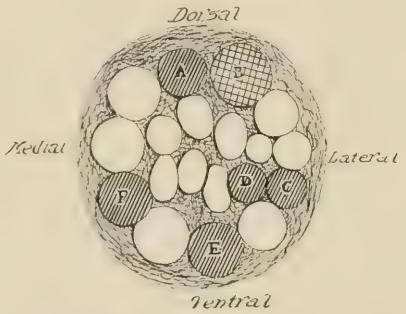


FIG. 654.—DIAGRAM OF PROXIMAL STUMP OF POSTERIOR TIBIAL NERVE IN LOWER HALF OF THIGH.

The trunk is seen to be made up of bundles of nerves which may be segregated as to their distribution. *A*, Communicans tibialis; *B*, to gastrocnemius and posterior part of soleus; *C*, to anterior part of soleus; *D*, to flexor longus hallucis; *E*, to tibialis posticus; *F*, to flexor longus digitorum. The other bundles are mostly motor tracts for the short flexor muscles and sensory tracts of the plantar nerves.

A rule which may be followed in all injuries of accessible nerves, in which the question of complete division or interruption of the nerve is involved, is that operation should be done if the reaction of degeneration is still present at the end of ten days.

Wounds of Nerves.—A wound partially through a nerve need not necessarily cause discoverable symptoms of paralysis; but if the wound is known to exist it should be sutured in order to minimize the possibility of neuralgia. A wound which divides a nerve completely or cuts off a sufficient number of fibers to cause discoverable paralyses should be sutured in order that regeneration and restoration of function may be secured. It is often difficult to distinguish between an injury that will undergo spontaneous repair and one that will be followed by permanent paralysis. A completely divided nerve may unite spontaneously, but usually it will not unless sutured.

To determine whether the continuity of a nerve has been lost and degeneration set in, as it will in all divided nerves, tests for the reaction of degeneration should be made. Without suture, it is possible for nerve tissue to regenerate across an interval of 2 to 4 cm. (¾ to 1¾ inches); but the bridging of even a fourth of these distances is rare. Usually cicatrix fills the gap and no nerve cells can penetrate it.

In suturing nerves it is not necessary that the exact fibers of the distal end shall be united to the proximal fibers with which they were originally continuous. Indeed, this would be impossible. A divided nerve may be rotated half a circle, united and resume its function. The central end of a flexor nerve may be united to the distal end of an extensor nerve and *vice versa* and coördinated function restored. But although this is possible, a better and quicker result will be secured if exact restoration of continuity is made.

Nerve Suture (Neurorrhaphy).—**Primary nerve suture** requires that a good view of the divided nerve should be had. If necessary the wound exposing the nerve should be enlarged. In the case of a bullet or stab wound dividing a nerve, in the interest of asepsis the wound should be sterilized by chlorin, phenol and alcohol, or by tincture of iodin. When possible in such cases the nerve should be exposed by an incision some distance away from

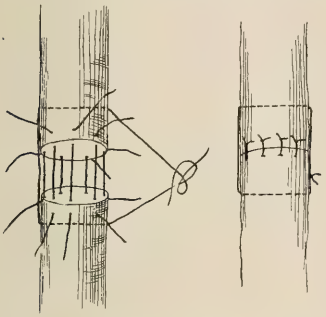


FIG. 655.—SIMPLE NERVE SUTURE.
Note short sutures and longer relaxation sutures.

FIG. 656.—OBLIQUE DIVISION AND SUTURE OF NERVE.

FIG. 657.—OBLIQUE SUTURE OF NERVE WITH DEEP RELAXATION SUTURE.

the accidental wound. Septic infection is fatal to the success of the operation. The nerve ends having been discovered, if they are ragged they should be squarely trimmed off. In bringing the nerve ends together, the trunk should not be twisted. Every care should be taken to have the divided fibers brought together as nearly as possible in their normal position. If this is not done, the motor bundles are united to sensory bundles, and much time is lost in restoration of function.

The suturing of divided nerves is done at once (primary nerve suture) or some time after the injury when the ends require to be freshened (secondary nerve suture). Primary suture should always be done when possible, but sometimes the presence of infection or other complication makes it inexpedient. Secondary suture is called for also if the primary suture has proved to be unsuccessful.

The ends to be sutured should fall easily into apposition. There should be no tension upon the suture. To accomplish this the limb should be put in such position as to relax the nerve, or, if necessary, the nerve should have traction in both directions made upon it to stretch it to the desired position. In doing this the nerve should be grasped by the fingers covered with gauze. This is not necessary unless there is loss of substance. Failing to bring together the ends, nerve-bridging is called for (see page 855).

Usually there is no tension required in suturing a cleanly divided nerve. The nerve should be handled gently. Fine mouse-tooth forceps take hold of the sheath. In the larger nerves two sets of sutures are used: deep and

superficial. The deep suture transfixes the nerve, is of fine chromicized catgut, and is introduced about 1 cm. from the wound. For nerves the size of the ulnar, one is sufficient. The musculospiral requires two, best applied at right angles to one another. The sciatic should have three. The nerve is held together, and these sutures gently tightened. Then the superficial sutures should be inserted. These should be of the finest catgut. They should be passed simply through the sheath of the nerve. Their chief function is to prevent lateral displacement. They need not be applied to the whole circumference of the nerve if so doing would require disturbing it from its bed (Fig. 655). If a nerve is divided obliquely the same principle is employed (Figs. 656 and 657).

After uniting the nerve the site of the union should be enveloped in fascia, muscle, or fatty or areolar connective tissue. By suturing about the wounded nerve a protecting envelope the success of the union is greatly insured. The surgeon should feel that he has left the nerve in a protecting canal. If material is not available in the neighborhood of the wound, it is best to cut out a piece of fascia from the outer side of the thigh. Less desirable, but quite effective, is heteroplastic material, such as a segment of a calf's vein or artery. The cuff should extend 1 or 2 cm. beyond the suture on either side.

Before closing the wound, hemorrhage should be controlled. Dead spaces should be sutured together, and every attention should be given to securing niceness of apposition in order that there shall be the least possible formation of new connective tissue. A splint should be applied to immobilize the parts. This splint should be adjusted in such a way that subsequent dressing can be done without removing the splint. Immobilization should be continued for two weeks, and quiet enjoined for still another week. After that the local health of the parts supplied by the nerve should be given attention. Massage, passive motion, electricity, vibration, or hot and cold applications should be used to keep up the nourishment, tone and suppleness of the paralyzed parts.

Restoration of function of the nerve should be expected in all cases which heal without infective irritation or suppuration, provided a good apposition of the nerve is secured. The function of the nerve may be expected to return in from two to three months.

Secondary nerve suture is required for conditions similar to those requiring neurolysis (excepting that scar tissue also between the cut ends must be dealt with. The retraction of the nerve-ends often makes it impossible to effect a union without some sort of plastic operation. The ends are involved in scar tissue, and it is unwise to begin the operation in this scar. The proximal end of the nerve is most easily found. This should be exposed well away from the scar, and the nerve then followed down to the old wound. A bulbous enlargement will be found on the proximal end, but the distal end usually tapers insensibly into the scar, and is smaller than normal. If there is difficulty in finding the nerve-ends an Esmarch rubber bandage will be of much help to induce anemia; but the bandage should be removed as soon as the nerves have been found. The surrounding scar tissue and the scar intervening between the nerve-ends should be removed, and the ends freshened. Judgment is required in determining how much of the nerve to sacrifice. The ends should be cut off evenly with a fine sharp knife, scissors cause damaging bruising. The ends should be cut away until the bundles of nerves, with not too much connective tissue, can be seen. Before proceeding with the freshening of the nerves it is well to determine how much can be sacrificed and still allow apposition without tension. Traction upon each end will gain considerable toward closing the breech. No suture

should be made with tension. The ends should lie together passively before a suture is applied. The neurorrhaphy is done in the same manner and with the same precautions as in primary suture. If an easy approximation can not be made, some form of nerve plastic to bridge the gap should be resorted to.

Not all wounds in the region of nerves, causing paralysis, demand exposure of the nerve. I have seen bullet wounds in which the bullet passed so near the nerve that the inflammatory exudate about the wound caused paralysis, and gave the impression that the nerve had suffered serious injury. Ultimate recovery took place. The absence of the reaction of degeneration will show that the nerve is intact.

Nerve Bridging.—This operation is done when there is a gap between divided nerve-ends which cannot be approximated. It has been shown

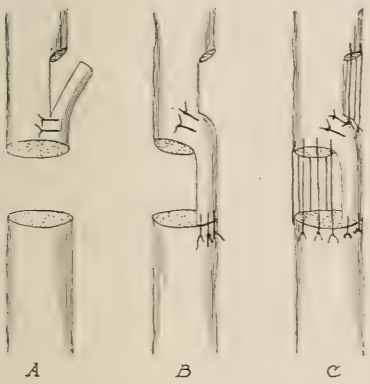


FIG. 658.—NERVE BRIDGING.

Operation for lengthening to bridge a gap. Strands of catgut are used to bridge the gap after the nerve plastic is completed. *A*, Slip cut free and secured by two sutures; *B*, slip sewed to bridge gap; *C*, strands of suture added to fill gap.

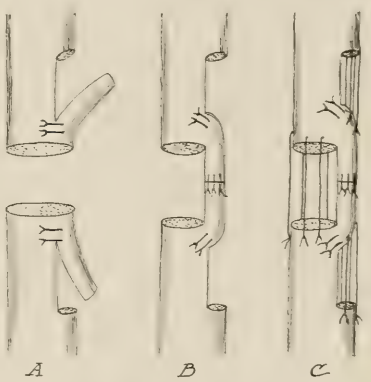


FIG. 659.—NERVE BRIDGING TO CLOSE A LARGER GAP BETWEEN TWO NERVE ENDS.

A, Cutting free a slip from each end; *B*, uniting slips; *C*, accessory nerve bridging with strands of thread added.

that under favorable conditions the nerve cells will grow through a gap of 1 or 2 cm., and even more in large nerves. But much better hope can be offered the patient by a plastic operation. Some of the same principles as have been described in operations on tendons apply here.

Autoplastic nerve bridging is done by means of a slip cut from one or both ends of the nerve and turned across the gap (Figs. 658 and 659). The operation should usually be combined with the following.

Heteroplastic nerve bridging is employed where for some reason an autoplastic operation cannot be done or where no living tissue from elsewhere can be secured. The ends should be freshened. Fine chromicized catgut is used to connect the two ends by a number of parallel strands forming a scaffolding along which the nerve fibers may grow. The space should be evenly filled with a catgut lacing. The musculospiral nerve should have about six such strands connecting the nerve-ends; the sciatic should have ten or twelve (Fig. 660). The wound must be free from blood. After connecting the ends with catgut the gap should be covered by suturing around it adjacent fascia, muscle or other tissue to make a protected canal. A piece of fascia should be cut to make a cuff which is wrapped about the nerve-ends

and the sutures. This tube protects the new growth of nerve tissue. If such structures are not available foreign material may be used: tubes made from decalcified bone or sheep's arteries, hardened in alcohol or chromicized. The results in these heteroplastic operations have been good, and gaps as great as 5 cm. (2 inches) have been made to fill with new nerve tissue. When reliable catgut is not at hand threads of fascia may be split from the patient's own tissues. If a tube connects the ends the catgut strands are not necessary. The best material for tubing is made of fascia lata which may be taken from some other part of the body. It should be attached to

FIG. 660.—NERVE BRIDGING WITH STRANDS OF CATGUT.

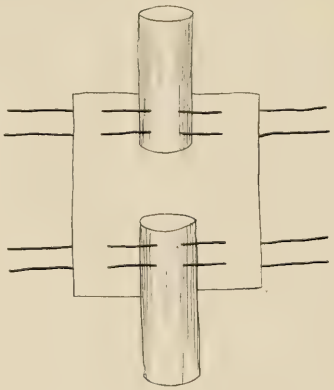


FIG. 661.—NERVE BRIDGING WITH TUBE OF FASCIA.

each end of the nerve, which should be enclosed in it. The tube thus formed should be larger than the nerve. The tube should be free from blood (Fig. 661).

Autoplastic nerve transplantation means transplanting another nerve from the same patient to fill the gap. When an important nerve loses more than 5 cm. (2 inches) of its continuity a segment of a nerve of lesser importance, such as the long saphenous, may be cut out and sewed into the

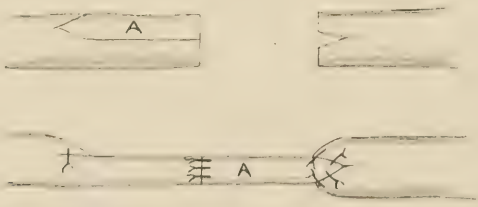


FIG. 662.—AUTOPLASTIC NERVE TRANSPLANTATION.
Nerve tissue is taken from the nerve-end. The segment of nerve *A* is cut free and inserted to bridge the gap.

breech. Another expedient consists in splitting off a part of the thickness of a larger nerve and using that. Or a branch of the damaged nerve may be cut out and used to mend the trunk. It sometimes happens that two nerves lose their substance, in which event one may be still further sacrificed to save the other. When a piece of nerve is to be transplanted, care should be taken to excise a piece somewhat longer than the gap lest it be found too short when laid in place. The piece should be sutured after the methods already described.

A method of transplantation which has much to commend it in the larger nerves consists in splitting the damaged nerve and taking from it the necessary material to fill the gap (Fig. 662). It is fatal to such an operation to leave about the nerve scar tissue or even the conditions that can produce scar tissue. If it cannot be surrounded by smooth fascia or muscle, it is better to make a new path for the nerve through muscle or some form of animal tubing.

Homoplastic nerve transplantation is the use of nerve from another person. Occasion sometimes arises when a limb has to be amputated in a healthy person. Such a limb offers nerve which may be used for filling a gap by immediate transplantation.

Heteroplastic nerve transplantation (nerve transplanted from another species of animal) has been successfully performed, but not with such uniform success as the autoplastic operations. Nerve for this operation has been taken from the dog; but the edible animals should lend themselves quite as well. The animal should be operated upon adjacent to the patient. Asepsis is essential to success. Every precaution must be taken. If the transplanted nerve is smaller than the other, two or more thicknesses may be placed side by side. The value of this operation is still in doubt. Ballance and Stewart have shown that the transplanted tissue does not remain alive or regenerate but simply acts as a scaffolding through which new nerve cells may grow, the same as catgut.

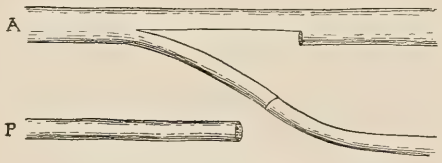


FIG. 663.—NERVE IMPLANTATION.
A slip is split from the active nerve (*A*) and sutured to the divided paralyzed nerve (*P*)

Nerve Implantation (Grafting).—The implantation of nerve is practised for the purpose of conveying central impulses through a functionating root into a paralyzed peripheral nerve, for conveying centripetal impulses back from a nerve whose own root has lost its function and for bridging gaps when there is loss of substance or continuity. These operations may be performed

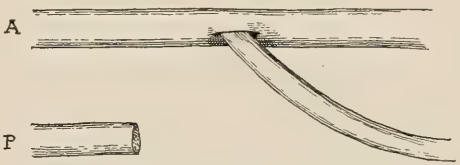


FIG. 664.—NERVE IMPLANTATION.
The paralyzed nerve (P) is divided and its distal stump implanted in an active nerve (*A*)

by complete division of the nerves and making an end-to-end suture. Where the nerves are large enough it is preferable not to divide completely a sound nerve, but either to split off from it a slip (Fig. 663) or to implant into it the affected nerve (Fig. 664). There is always the possibility that nerve suturing may not be successful; and it is therefore best not to have sacrificed a whole nerve when a third of the thickness or a half of the nerve would have answered, while the intact two-thirds or one-half may carry on

its function. Slips from the active nerve may be united with both ends of the divided paralyzed nerve (Fig. 665). One slip from the active nerve may be implanted (Fig. 666).

In the case of a nerve which has lost so much substance that approximation is not possible, if there is an adjacent nerve running near the gap, the two ends, proximal and distal, may be engrafted into this nerve and the

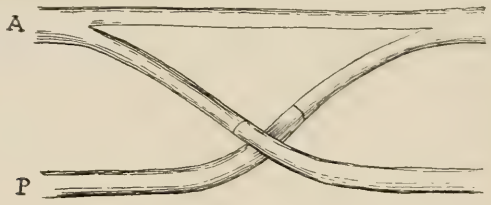


FIG. 665.—NERVE IMPLANTATION.

Slips from the active nerve (*A*) are united with both ends of the divided paralyzed nerve (*P*)

intervening stretch compelled to convey the impulses of both (Fig. 667). In some cases a lateral union can be made between a paralyzed and a normal nerve without dividing either (Fig. 668). The importance of the function of the nerves must also be considered in planning these operations, especially in considering the division of a nerve. A slip of the paralyzed

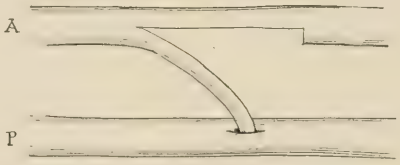


FIG. 666.—NERVE IMPLANTATION.

A slip from the active nerve (*A*) is implanted in the paralyzed nerve (*P*).

nerve may be implanted in the active nerve (Fig. 669). A slip may be taken from each nerve and united by end-to-end suture (Fig. 670).

The utmost gentleness should be employed in handling the nerves. The sutures should be applied according to the methods described under nerve suturing (page 853). A fine, sharp knife should be used for dividing nerves. In making lateral implantation, the nerve cells should be exposed and axis cylinders brought into contact. The nerve fibers should be implanted

FIG. 667.—NERVE IMPLANTATION.

Ends of the divided paralyzed nerve (*P*) are implanted in the active nerve (*A*).

in the direction toward which it is desired that the impulses shall flow. Sutures should be applied so as to constrict the fiber as little as possible.

In implanting into a longitudinal slit, the axis cylinders of the implanted nerve may best be exposed by cutting the end in the shape of a wedge. When a nerve end is laterally implanted upon another nerve it is well to divide the sheath of the latter transversely, split the end of the former and fasten it astride (Fig. 671). The nerves should be held together wherever

possible by sutures involving the sheaths and not the substance of the nerves. Lateral implantation without division of nerves, or with division only of paralyzed nerves, is the operation of choice (Fig. 672).

The results in these operations, when carefully done, are most encouraging. Successful grafting has been done between the nerves of the arm; the

FIG. 668.—NERVE IMPLANTATION.

Lateral implantation of paralyzed nerve (*P*) into active nerve (*A*) without division of either. The sheath of *P* should have been removed at the place of implantation.

internal and external popliteal; the facial, spinal accessory, and hypoglossal, and the anterior tibial and musculocutaneous. In the common injuries of the musculospiral nerve, if there is loss of substance, and this often becomes necessary in excising bulbous ends, the two stumps may be imp'anted into the median.

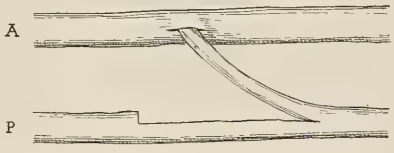


FIG. 669.—NERVE IMPLANTATION.

Slip of paralyzed nerve (*P*) implanted into active nerve (*A*).

In paralysis of the anterior crural nerve of one side, as occurs in poliomyelitis, it is possible to isolate the nerve of the sound side, and its branches from a point just above the knee up to Poupart's ligament. The diseased nerve of the other side, after being thoroughly tested and an absence of all electric reactions found, is divided above Poupart's ligament at a point

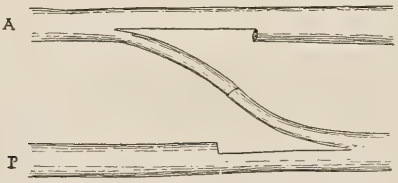


FIG. 670.—NERVE IMPLANTATION.

Slip from each nerve—active (*A*) and paralyzed (*P*)—united by end-to-end suture.

as high as possible. A subcutaneous tunnel is then made in front of the pubes, and a good-sized branch of the sound nerve is sutured to the distal stump of the divided nerve of the other side (D. Maragliano: Presse Médicale, vol. xx, No. 85). This same principle may be carried out with the sciatic nerve, making the union across the perineum. It has been applied in connection with the brachial plexus, a cord from one side being carried across the median line and united with the other side.

In any of these operations nerve bridging with a tube of fascia may be added to the technic if necessary.

Nerve Stretching (Neurectasy).—This operation is required as a preliminary to nerve suture when the ends do not lie in easy contact. As a therapeutic measure stretching is employed to break up compressing and irritating adhesions which are causing neuralgia or muscular spasm. After the operation of neurolysis (freeing the nerve from adhesions), symptoms

FIG. 671.—NERVE IMPLANTATION.

Method of uniting end of nerve to side of undivided nerve. The sheath is incised and retracted. The incision involves a few superficial fibres. The split end is then placed astride of the nerve and sutured in the incision.

may persist which can be relieved by stretching. The operation is of no value in central lesions. It must stretch the nerve at the site of the disorder.

The nerve should be exposed at the seat of disease, or as near to it as possible, and isolated for a sufficient distance to enable the surgeon to grasp it. It should be held between the fingers wrapped in gauze and traction made so as to stretch the nerve where it is involved in adhesions. The advice is given to stretch it in both directions, but there is no value in stretching normal nerve. In many cases the seat of the lesion cannot be definitely

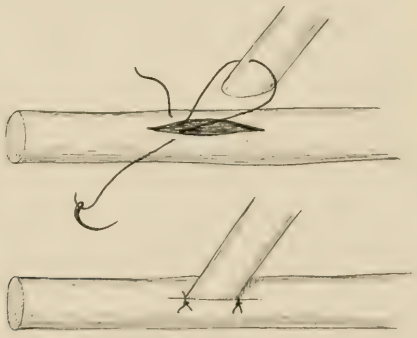


FIG. 672.—NERVE IMPLANTATION.

Technic of lateral implantation of nerve. The sutures are passed through the sheath and superficial fibres.

known, in which event traction may be made both proximally and distally. The degree of traction is a matter of judgment for the surgeon. The strongest traction may be made on the peripheral part. A nerve exposed near its exit from a bony foramen is in danger of being torn in two by too strong traction.

A force of more than 90 kilos (180 pounds) is required to break the great sciatic nerve in the upper part of the thigh, but not more than 25 kilos (50 pounds) of traction need be applied as a therapeutic measure. The nerve should be pulled until a distinct lengthening is secured. If perineural adhesions can be discovered they should first be dissected away. Some surgeons

have attempted to regulate the pull with mathematical accuracy by attaching a dynamometer to the nerve through a band of gauze. The sense of touch and the surgeons judgment, as applied through the fingers, are better.

Stretching may sometimes be done, without exposing the nerve, by forcible flexion and extension of joints. For example, the sciatic may be stretched by extending the leg and strongly flexing the thigh. This operation is often of service when combined with deep massage.

Neurotomy.—The division of a nerve may, be called for to produce temporary paralysis of either a sensory or motor nerve. As a therapeutic procedure in neuralgia it has been largely abandoned because the nerve usually soon unites and the neuralgia recurs, and because there are other more effective means of treatment.

Neurectomy.—The excision of a portion of nerve is employed where it is desired to make the paralysis of the nerve permanent. The operation is employed in neuralgia; but it is of value only in cases in which the lesion causing the pain is distal to the site of operation. If the lesion is central to the operation it will not be of avail. A segment of nerve must be removed sufficiently large to prevent regeneration. This means 2 to 4 cm. (¾ to 1¾ inches). The tendency to repair may be defeated by interposing some foreign material. In bony canals, silver foil, a silver plug, or bone may be used.

Bone is the most useful material for plugging a bony canal. After avulsion of the nerve, the canal should be denuded of periosteum with a sharp curet, saw, chisel or file. A plug of fresh bone, taken from the tibia or elsewhere, should be inserted into the canal. The infraorbital canal may be closed by cutting out a plate of bone, having the foramen in its middle, and inserting a solid plate of the same size taken from the tibia. The infradental canal may be exposed by trephining at the angle on the outer side of the jaw, removing the lining of the canal with a sharp curet, and replacing the button of bone so that the half of the canal on the button lies at right angles to the natural course of the canal (A. B. Kanavel: Jour. Am. Med. Assoc., Oct. 10, 1914).

To add to the assurance of success, after removing as much of the nerve as is easily accessible, each end should be grasped with forceps, slowly twisted around the forceps, and thus pulled out. This procedure gives a much larger percentage of permanent cures than simple excision.

Even when 5 cm. (2 inches) of nerve are removed and the distal branches and the proximal root twisted and avulsed, recurrence of neuralgia often takes place. This is because of collateral branches taking up the impulses from the lesion and conveying them centrally, because of a neuritis developing in the injured nerve, or because of the presence of lesion still existing central to the removed nerve.

The treatment of neuralgias in the different nerves is dealt with elsewhere (page 862).

Efferent nerves or *mixed nerves* which convey muscular impulses to important muscles, of course, should not be treated by any of the measures which paralyze or destroy the nerve, unless the paralysis of the muscle is desired.

NEURITIS

Multiple neuritis does not come within the scope of surgery. Surgery deals with simple and localized neuritis. Much can be done to prevent these conditions. In all neuritides the cause should be sought and, if possible, removed. Infection of wounds can be prevented and cured. Bone fragments and tumors pressing upon nerves can be removed. Traumatism from

pressure upon the arm nerves during operations under general anesthesia can be guarded against. Pressure of splints and crutches can be controlled. Prophylaxis can be applied to the constitutional irritations such as arise from syphilis, alcoholism, intestinal fermentations and lead and other drug poisons.

Acute infective neuritis should be treated the same as acute infective inflammation in other parts. Rest should be secured by bandages or splints. An increase of hyperemia should be induced. This may be accomplished by wet hot packs or by dry heat. The tendency of the inflammation is to subside. Acute irritative or noninfective neuritis should receive the same treatment after the cause has been removed.

Chronic neuritis is relieved by the same measures which are applied to the acute forms. It is also amenable to the nonoperative measures which are used in neuralgia. The continuous galvanic current may be applied with the anode along the nerve. Ten to 20 milliamperes may be used for five minutes daily. Counterirritation along the course of the nerve may be made with iodin, mustard or the actual cautery. But hot packs, either wet or dry, are to be preferred. Constitutional derangements should be looked for and treated.

In all neuritides pain should be relieved. If the treatment of the neuritis alone does not accomplish this, anodynes may be employed. In some cases in which the pain is aggravated by swollen vessels, cold applications will give relief. In using either heat or cold, the presence of sensory paralysis and local trophic disturbances demand that care shall be taken lest too much heat or cold cause gangrene. Morphin must be used with the utmost care to avoid producing the morphin habit. Among the remedies which may be tried before morphin is used are acetanilid, compound powder of acetanilid, acetphenetidin, codein, aconitin, atropin, chloralformamid, hyoscin, cannabis indica, apolysin, bromids, butyl-chloral hydrate, monobromated camphor, citrophen, dionin, euphorin, gelseminin, kryofin, lactophenin, neurodin, triphenin, coniin, quinin (in malaria) and salicylates and the like in autotoxemia. Cocain, urea and quinin, or other local analgesics may be injected around the painful nerve.

The tone of paralyzed muscles should be maintained by massage and the interrupted galvanic current after the neuritis has subsided. If deposits of inflammatory tissue are left in the nerve sheaths, causing neuralgia, trophic disturbances or muscular trouble, its absorption should be hastened by massage, alternate hot and cold applications, vibration or electricity. If these means do not suffice, nerve stretching will often be of service.

Traumatic neuritis requires rest especially. Autotoxic neuritis requires that the toxic focus from which absorption is taking place shall be cleaned out, whether it be a septic osteitis, abscess, cellulitis or a septic intestinal canal. In the latter case laxatives and a much restricted diet are indicated. Many of these neuritides are the result of the accumulation of noxious products in the tissues, and are best remedied by fresh air, deep breathing, simple food and exercise. A patient suffering severe pain with such a condition should not be kept quiet in a closed room and given anodynes. The neuritis of poisoning from lead or other known substances requires the specific treatment for that peculiar condition. Syphilitic neuritis is so common that antisyphilitic treatment is effective in a large proportion of cases.

NEURALGIA

In the treatment of neuralgia the most important step is the discovery and elimination of the cause. The causes are quite similar to those which

are described under neuritis. Neuritis is an etiologic factor in a large proportion of the neuralgias. Much that is described in the treatment of neuritis is applicable in neuralgia. The latter differs from the former in that the lesion is often so slight that it cannot be discovered, the pain is often reflex and remote from the lesion, individual susceptibility plays a prominent rôle, and the pain instead of being constant is more apt to be paroxysmal.

The causes to be looked for and treated are neuritis, and the conditions which cause it. The irritative factor may produce pain in a nerve without going on to a pronounced inflammation. Local causes which produce compression of nerves, such as tumors and inflammatory deposits, should be removed. Bulbous enlargements upon the proximal side of wounded nerves require extirpation.

Constitutional conditions, as in neuritis, play a prominent rôle. Autointoxications should be corrected (see Neuritis, page 861). Anemia, malaria, syphilis, diabetes, sepsis, hysteria and disorders which depress the vitality are common etiologic factors. If a local cause is not known, no surgical operation should be attempted until constitutional treatment has been tried. Errors of hygiene should be corrected and the patients general health brought up to the best possible condition. This means attention to the mental health, eye accommodation, nasopharynx, teeth, breathing, gastro-intestinal condition, and so on through the body. Often a change of residence to a warmer climate is of help. In the meantime, local measures for relief may be applied.

For the immediate relief of pain, if the local treatment is not effective, the same *drugs* as have been recommended for the pain of neuritis may be used. Morphin is the most effective but the most dangerous, and its employment should be a last resort. A coal-tar analgesic, such as acetanilid, protected by a stimulant, such as caffein, may be given with aconitin. The latter drug may be given in doses of 0.0003 Gm. ($\frac{1}{200}$ grain) every four hours until physiologic effects appear. As much as 0.002 Gm. ($\frac{1}{30}$ grain) of aconitin may be given daily. The efficacy of this treatment is increased by active purgation.

Strychnin sulphate is effective in many early cases. It is given hypodermatically once daily. The beginning dose is 0.002 Gm. ($\frac{1}{30}$ grain). This is increased up to 0.008 to 0.016 Gm. ($\frac{1}{8}$ or $\frac{1}{4}$ grain). The large dose is given for three or four days and then the dosage gradually diminished.

Internal medication is of service in improving the intestinal condition, in stimulating metabolism, and in neutralizing toxins. Among the drugs used are arsenic, gold chlorid, nucleins, iodids, mercury, quinin, iron, methylene blue and salicylates. The salicylates, pushed to tolerance, are effective in many cases (see Neuritis above).

A popular prescription consists of a pill, each containing 0.001 Gm. ($\frac{1}{60}$ gr.) arsenic iodid, 0.006 Gm. ($\frac{1}{10}$ gr.) each alcoholic extract of belladonna leaves and morphin, and 0.005 Gm. ($\frac{1}{12}$ gr.) each powdered extract of gentian and powdered extract of aconite. One to three of these pills are taken daily.

These constitutional and medical measures will naturally have been tried before the case comes to the hands of the surgeon, who should proceed at once with the more radical methods of treatment. There are many local measures of treatment.

Local hyperemia is of much service (see Hyperemia and Counterirritation, pages 229 and 237). It may be induced or increased by applying the actual cautery to the skin. This is done as follows: The patient's eyes are covered; the cautery, heated to a cherry red, is taken in hand, and rapidly brushed back and forth, approaching the skin closer and closer: it is caused to pass

so closely to the skin that its heat causes hyperemia; in addition to this the cautery in its rapid motion is made to flick the skin occasionally until the skin is marked by a few red stripes. In the presence of neuralgia, this treatment is not so painful as one might suppose.

Hyperemia may be induced by hot air, wet hot packs, hot salt-bags, hot poultices, mustard, iodin, cantharides, capsicum, chloroform, croton oil, peppermint, oil of turpentine or other rubefacients.

Vibratory massage over the painful area and along the nerve is often useful. The constant *galvanic current*, 8 to 15 milliamperes, may be used, the positive pole covering the whole painful area and the negative pole applied to the spine. Both of these poles should be of large size. The current should continue for half an hour to an hour daily. The faradic current is sometimes effective if used as strong as the patient can bear it. It is applied to the nerve from its point of bony exit for a short distance along its course.

Percutaneous injections of medication around the nerve trunk or in its substance are among the most effective and simple treatments of neuralgia. Three forms of medication are employed: (1) those which, perhaps, do nothing more than produce hyperemia; (2) those which have local analgesic properties, and (3) those which have a selective affinity for nerve cells and cause a certain degree of inhibition of impulse-carrying power or degeneration. There is no sharp dividing line between these. One thing is certain: all belong to the first group. Salt solution, water, air, phenol, antipyrin, and other coal-tar products, alcohol, oxygen, cocain and its allies, and osmic acid are used.

At present **alcohol** is most in favor. It, perhaps, produces both local hyperemia and a degenerative change in the nerve substance. The injection should be just outside of the nerve, if the pain is not severe and the nerve is superficial, but into the substance in the severe neuralgias. Degeneration results if the nerve substance is injected. If the nerve is exposed the injections may be made with advantage under its sheath. The degeneration is usually temporary, and function is ultimately restored. The solution most used is 85 per cent. alcohol, containing 0.25 Gm. (4 grains) of cocain to 30 c.c. (1 ounce) of distilled water. About 2 c.c. of this solution are injected in trifacial neuralgia. This treatment may be applied either to sensory or motor nerves. The paralyses of sensation and motion are slight or temporary, but pain is relieved. Repeated injections may be required. Usually the treatment is followed by relief which may be permanent or which lasts for several months. The relief from pain in trifacial neuralgia is for a shorter period than after osmic acid injection or avulsion. In most cases the neuralgia returns in four to six months, but rarely as intense as before. The injection should be made as near the origin of the nerve as can be done with ease. It may be repeated any time during the first week if there is not much edema. This should be done if the nerve was not penetrated at the first injection. After relapse has taken place reinjection gives another period of relief (for Technic, see page 866).

In *painful wounds, nerve blocking* by injecting the nerve with 60 per cent. alcohol, is most useful. Alcohol of this strength interrupts sensation but not motor impulses.

In the treatment by **osmic acid** injections, about 1 c.c. of a 1 or 1.5 per cent. solution is used. The injection may be made around the nerve, as near to it as possible, or the nerve may be exposed and the fluid introduced under its sheath in several places or in its substance. The best results are secured by exposing the nerve and making the injection directly into the

nerve substance. Relief lasts for from twelve to eighteen months. In some cases recurrence has not appeared for three or four years. Second injections give even a longer average period of relief than the primary injection (see also Spinal and Sacral Anesthesia, pages 155 and 163).

The injection of **oxygen** about the affected nerve has proved beneficial in cases of intercostal and sciatic neuralgia.

Postherpetic neuralgias are not often benefited by injections.

Chronic fibrositis, the painful localized indurations, is cured by injecting alcohol deeply into the point of the most intense tenderness.

Operative treatment is called for when these measures fail to give relief. The operations are nerve stretching, excision of nerve, neurolysis, division of nerve, and the excision of nerve root ganglia. The latter operations are described in connection with the special parts (see also Injection of Nerve Roots, page 152).

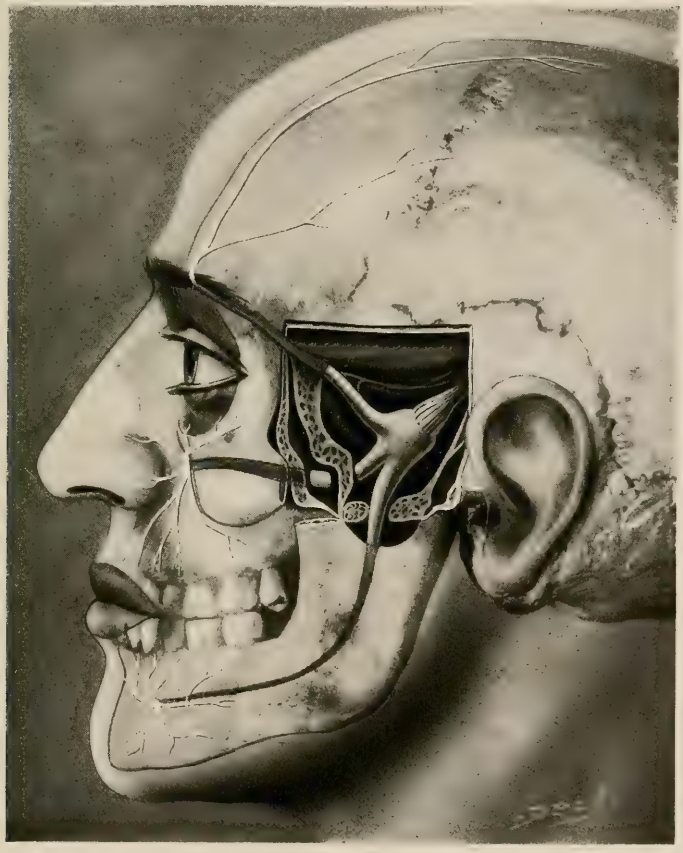


FIG. 673.—ANATOMY OF TRIFACIAL NERVE.
The gasserian ganglion is seen giving off its trifacial branches. (*After Campbell.*)

NEURALGIA OF SPECIAL NERVES

Trifacial Neuralgia.—Neuralgia of the trifacial or fifth cranial nerve (Fig. 673) is the most common of the severer neuralgias. As it varies much in intensity, it calls for different treatments. The mild form requires the con-

stitutional measures above described. Errors of accommodation in the eyes are common etiologic factors, and should be carefully sought for by a competent oculist, and corrected. These measures should be supplemented by local hyperemic treatment. Morphin should not be used except rarely and exceptionally and then only administered by the physician. When the general health has been improved as much as possible and no causative factor has been discovered, or all possible causative factors removed, and the pain persists, the treatment by perineural injections is indicated.

The neuralgia minor is the milder form which involves but one or two of the branches. In the first branch, eye disease, nasopharyngeal disease, malaria and sepsis should be looked for. In the second and third branches, diseases of the teeth and jaws, and intestinal toxemias should be suspected. If the pain does not correspond to the distribution of the nerve, and there is tenderness of the skin between attacks, the disease is of reflex or visceral origin. The neuralgia major, or *tic douloureux*, is usually of central or ganglionic origin, although it may begin as a result of peripheral irritation.

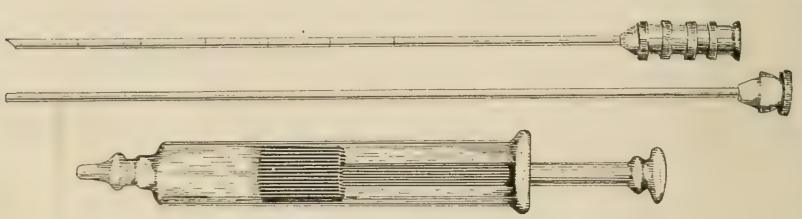


FIG. 674.—SYRINGE, NEEDLE AND STYLET, USED FOR INJECTIONS OF NERVES IN NEURALGIA.

Medical and constitutional treatment should not be persisted in if it does not seem to be effective. Galvanism may be tried. The injection of alcohol should be the next procedure. This failing, neurectomy of the affected branches is called for. The last resort is operation upon the Gasserian ganglion.

The *technic of alcoholic injections* is as follows: The best solution is 60,70, 80, or 90 per cent. alcohol, containing 0.25 Gm. (4 grains) of cocain to the 30 c.c. (1 ounce). Most surgeons use cocain hydrochlorate, 0.1 Gm. (2 grains), alcohol, 13.5 c.c. (2½ drams), and distilled water, 15.5 c.c. (½ ounce). The parts are prepared as for an operation or the skin may be sterilized by a drop of tincture of iodin. Usually no anesthetic is required. Gas may be given to nervous patients. The pain is but slight. General anesthesia is highly undesirable because it prevents the surgeon knowing when the nerve is pierced. The injection is made with a straight needle 6 to 10 cm. long (2½ to 4 inches). The needle should be marked in centimeters. About 1½ to 2 c.c. (20 to 30 minims) are injected. For injecting the second and third divisions at their exit from the skull a needle 10 cm. long is used. It should be about 1.75 mm. thick, and provided with a stylet flush with the point (Fig. 674). The needle should be passed slowly and the nerve felt for. After the nerve is touched the stylet should be withdrawn. If blood flows, the needle should be removed, or the stylet should be reinserted and left till the bleeding ceases. It is never wise to inject alcohol into a needle full of blood, because the action of the alcohol is wasted on the blood, and the hardened clot is pushed into the nerve or elsewhere; the surgeon never knows that the needle is in the nerve; he hopes it is. The operation should be done in the presence of a skull upon which the surgeon may refresh his memory of the bony landmarks.

The external foramina through which the branches of the trifacial pass to the face are three on each side. They may be located by drawing a vertical line through the plane of the pupil of the eye and the interval between the two bicuspid teeth. This line crosses the supraorbital, infraorbital, and mental foramina (Fig. 675).

To reach the *first division*, the injection should be made at the supraorbital notch or foramen. It is dangerous to attempt to reach the first division at the back of the orbit.

The *second division* is injected at the foramen rotundum. The needle should be inserted at the lower border of the zygoma, 0.5 cm. (3/16 inch)

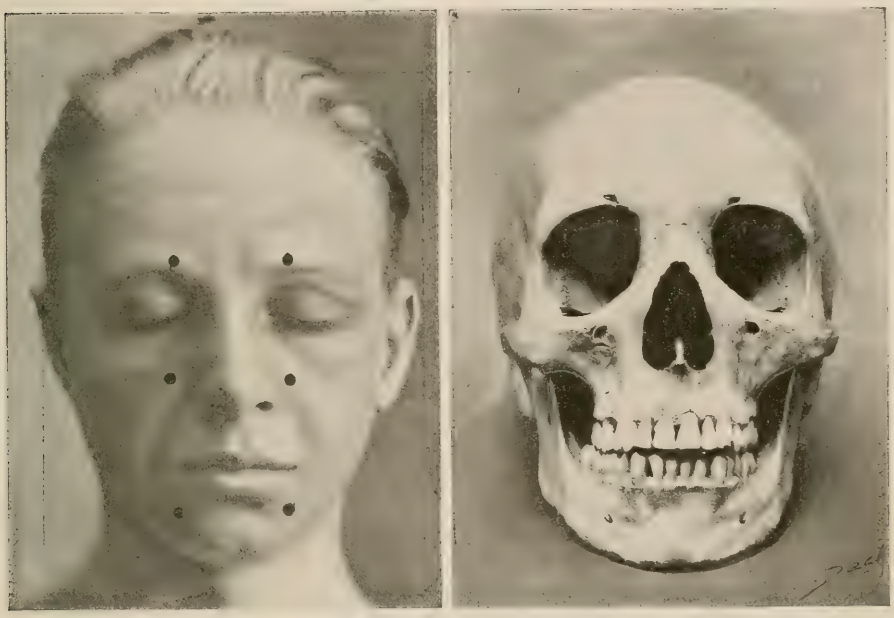


FIG. 675.—SHOWING LOCATIONS OF SUPRAORBITAL, INFRAORBITAL AND MENTAL FORAMINA FOR NERVE INJECTION.

behind a vertical line drawn from the posterior edge of the orbital process of the malar bone. This is about 6.5 cm. (2½ inches) from the middle of the external auditory meatus (Figs. 676 and 677). It should pass inward and slightly upward and very slightly backward for a distance of about 5 cm. (2 inches). The upward inclination should be about 40 degrees. In taking this course it passes through the pterygomaxillary fissure and strikes the external pterygoid plate or passes in front of its anterior border and enters the sphenomaxillary fossa, on the posterior wall of which lies the foramen rotundum near the base of the pterygoid plate. If the needle passes farther than 5 cm., except in broad skulls, it is apt to reach the sixth nerve which lies at the apex of the fossa. The upward inclination of the needle should bring the tip, after it has passed in 5 cm., at the level of the lower end of the nasal bones. The pterygoid plate is a valuable landmark. The foramen rotundum lies about 1 cm. (2/5 inch) internal to its anterior border. If the needle does not strike the plate but enters the fossa in front of it, it is well to withdraw the needle slightly and pass it further back, feeling for the

plate. Then the needle is pushed in along the front of the plate about 1.5 cm. ($\frac{9}{16}$ inch) further, making the total depth of 5 cm. If the needle strikes the nerve the patient will have pain at the site of puncture, or at the nose, lip or cheek. To avoid the pain of the alcohol, it may be preceded by 3 drops of cocain solution in the nerve. If the coronoid process is in the way the needle must be entered 4 cm. ($1\frac{1}{2}$ inches) in front of the middle of the external auditory meatus, passed behind the process, slightly upward and forward.

The second division may be injected as it emerges from the infraorbital canal. A needle 3 cm. ($1\frac{1}{4}$ inches) long is passed backward through the cheek at the level of the upper border of the ala nasi and 5 mm. ($\frac{3}{16}$ inch) external to it.

FIG. 676.—NEEDLE PLACED FOR INJECTION OF SECOND BRANCH OF TRIFACIAL NERVE. Side view.

FIG. 677.—INJECTION OF SECOND BRANCH OF TRIFACIAL NERVE. Front view.

The *third division*, or inferior maxillary nerve, may be reached by several routes. Below the zygoma, the needle should be entered in the triangle bounded by the lower border of the zygoma, and the coronoid and condyloid processes of the lower jaw. It should be entered 1 cm. ($\frac{2}{5}$ inch) in front of the preglenoid tubercle, and pass inward, and very slightly upward and backward (Fig. 678). This point is 2.5 cm. (1 inch) in front of the anterior root of the zygoma, or midway between the coronoid and condyloid processes, close under the zygoma.

The point of the needle may strike the base of the sphenoid. This is a good landmark, as the needle is then easily slipped into the foramen ovale. When the point strikes the external pterygoid plate, it should be moved backward until it passes behind the plate, where it meets the nerve. As soon as the nerve is touched, pain is usually felt at its distribution. When the nerve is touched, the stilette should be removed, the needle should be withdrawn slightly, and then passed into the nerve. The nerve is punctured when the point is about 4 to 5 cm. ($1\frac{3}{5}$ to 2 inches) from the skin surface. In fat faces it may have to pass in to a depth of 6 cm. ($2\frac{1}{2}$ inches). It is a

good plan to inject a few drops of cocain solution after the nerve has been struck, as evidenced by deep pain at the needle point or at the lower lip, jaw or tongue. If the cocain causes anesthesia of the lower lip and tongue, the alcohol may be injected.

The third division may be reached above the zygoma. The needle should be entered just above the zygoma on a line 1 cm. anterior to the pterygoid tubercle, and pass inward and very slightly downward.

If the needle has been directed too far backward pain in the ear may be felt. This is due to puncture of the eustachian tube. The needle should be slightly withdrawn and the nerve sought for farther forward. This is a different pain from that caused by puncture of the auriculotemporal nerve which supplies the external ear. In that event, the needle should be passed in for another millimeter, and the injection made.

FIG. 678.—INJECTIONS FOR NEURALGIA.
Showing positions of needles to inject second (2) and third (3) branches of trifacial nerve.

In most cases of trifacial neuralgia pain is referred to the upper jaw also and often to the palate. If the infraorbital nerve has been injected, the relief is not complete, and the second division must be approached nearer its origin at a point posterior to the posterior dental branches, the branch to Meckel's ganglion and the palatine branches. If the neuralgia involves these latter branches, no injection should be made peripherally to them, but only an injection at the foramen rotundum should be considered.

Injections of the infraorbital nerve may control neuralgia of the second division for a time. Injections of the periphery of the third division in the mental foramen are rarely worth making. The third division should be injected in the foramen ovale.

Injections of the third division at the foramen ovale give relief of pain in *incurable carcinoma of the tongue.*

Injection of the Gasserian ganglion is to be performed if injections of the branches at the base of the skull do not give relief. It is done through the

foramen ovale. The needle is passed as for injecting the third division. The under surface of the sphenoid is felt with the tip of the needle. The needle is then slipped along into the foramen. If the needle strikes the spine of the sphenoid, which lies just behind and below the foramen, it serves as a guide and indicates that the point must be moved forward. If the foramen is not found, the external pterygoid plate should be tried as a guide, and the point caused to pass just back of its posterior edge. The foramen may lie abnormally forward or backward in peculiarly shaped skulls. After the nerve has been punctured at the foramen, alcohol is injected slowly, a few drops at a time, until it reaches the ganglion. The injection passes up the third division to the ganglion. The operation is not planned to pierce the ganglion with a needle. It will be observed that anesthesia first appears in the third division. Then as more alcohol is injected the anesthesia next spreads to the distribution of the second and first divisions. By the time 1 or 1.5 c.c. (15 or 20 minims) have been injected the whole distribution of the fifth nerve is paralyzed. After this 0.5 c.c. (7 drops) more may be injected if this brings the total amount not above 1.5 c.c. If total anesthesia continues for an hour, the eyelids should be closed with rubber tissue and a gauze dressing to prevent keratitis. If the anesthesia persists for ten hours the paralysis is more permanent and the eyelids should be sutured shut, leaving space at the inner canthus for daily saline irrigation.

The extent of the anesthesia should be tested after each injection. At the conclusion in most cases the anesthesia begins to disappear after five or ten minutes in the first and second divisions. By the end of twenty-four hours the anesthesia will have nearly faded away from all but the area supplied by the third division. Repeated injections may be necessary, but this treatment is so much less hazardous than resection of the ganglion, that it should always be used before resection is considered.

Another method of reaching the foramen ovale is to pass a finger in the mouth and identify the location of the foramen. Then with this as a guide the needle is passed through the cheek.

The *results of alcoholic injections* are cessation of pain and a local temporary hard swelling. This edema gives a sense of uncomfortable tension. Headache sometimes lasts a day or two. When the alcohol comes in contact with motor nerves, the paralysis which it produces subsides in about a year. The injection of alcohol in sensory nerves causes the immediate cessation of pain. If an injection has reached the substance of the nerve, relief from pain is instantaneous, and lasts from six months to four years. When the pain returns, repetition of the injection seems always to be effective.

H. T. Patrick reported 500 of these deep injections. In the case of the middle branch, he missed the nerve in 25 per cent. of the cases, 42 per cent. were partially successful, and 33 per cent. were good. In the inferior branch, about the same results were secured. In less than 20 per cent. of cases was the first attempt successful. Skill and experience are important prerequisites for success.

There is practically no danger. Of the thousands of injections that have been made there are no reports of fatalities. The operation may be done in the office; the patient may lie quietly for a little while, and go home. Relief is secured even in neuralgia major. The freedom from pain may be expected to last for from six months to four years. Quite invariably, if the injection reaches the nerve, it gives relief. If it is not sufficiently near the nerve the relief may be but for a short period or not at all. Many apparently permanent cures are made. The operation is successful in cases in which neurotomy or neurectomy has been done.

In cases of neuralgia major, which remain intractable to treatment of the individual nerve roots, and in which attempts to inject the Gasserian ganglion by way of the third division have failed, the foramen ovale and the third division may be exposed by resection of the zygoma, and the injection into the nerve made with the aid of sight (see Operations on Nerve Roots below).

Neurectomy is indicated in a certain proportion of cases of neuralgia minor, involving a single nerve (or not more than two of the three divisions) and which are due to peripheral irritation which cannot be removed. Alcohol injections in these cases will give temporary relief but neurectomy may be expected to give permanent relief. It cannot often be definitely determined that the lesion is wholly peripheral. In old cases, even if it were at first peripheral, ascending degenerative changes may have carried it centrally.

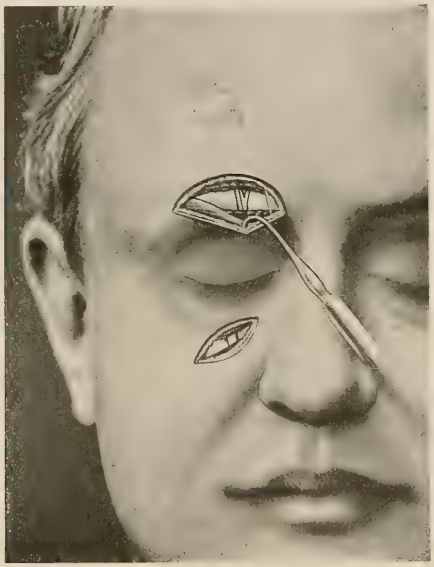


FIG. 679.—EXPOSURE OF SUPRAORBITAL AND INFRAORBITAL NERVES.

Such operations should be done early. In well-established cases of neuralgia major the peripheral operations are of little value. If recurrence takes place the nerve root must be removed still higher up. The branches of the trifacial nerve possess a strong power to regenerate. To prevent regeneration, the nerve must be removed from its bony canal and the canal closed with a plug of silver foil, a silver screw or bone. Such is the treatment applied to the infraorbital and supraorbital canals after avulsion of the nerves.

Slow avulsion, taking fifteen or twenty minutes to twist out both the peripheral and distal trunks, is of decided value. As much as 4 or 5 cm. (1½ or 2 inches) of the central end, and 2.5 or 10 cm. of the peripheral end may be removed by slowly winding the nerve around a clamp by a screwing motion.

The *ophthalmic* or *first division of the fifth nerve* is exposed by an incision 3 or 4 cm. (1 or 1½ inches) long, following the supraorbital margin, in the brow-bearing portion of the skin. The supraorbital notch is at the junction of the middle and inner thirds of the supraorbital margin. The incision should be laid so that the notch comes in its middle. Small branches of the nerve will be encountered emerging through the orbicularis muscle. These should be spared. The muscle fibers are to be separated by blunt dissection.

The notch is easily felt. The nerve, with the vessels, lies close to the bone. Usually it will be found under the periosteum in the notch. The orbital connective tissue should be depressed and the anterior part of the roof exposed. By incising the periosteum and reflecting it back, the nerve is uncovered. The nerve is lifted out of its bony bed in the roof of the orbit. The trochlear and frontal branches should be dissected free. The nerve, being well exposed, is divided posterior to the trochlear branch. The root is then grasped with a clamp, twisted and avulsed. The distal branches are then avulsed. The nasal branch may be reached through the inner end of the incision as it emerges from the anterior ethmoidal foramen (Fig 679).

The *superior maxillary* or *second division of the fifth nerve* is most easily reached at the infraorbital foramen, through which it emerges. The foramen is about 1 cm. below the inferior orbital margin, at the upper end of the canine fossa, in a vertical line drawn between the two bicuspid teeth. A slightly curved incision, in line with the natural folds of the skin, is carried along the lower border of the orbit. The incision should be about 2 cm. (¾ inch) in length, and should have the foramen below its center (Fig. 477). If it is desired to avoid a skin scar, the foramen may be reached through the mucous membrane of the mouth, the periosteum being incised above the alveolar process and stripped back to the foramen. The skin incision gives a better exposure.

The nerve having been exposed at the infraorbital foramen, the periosteum should be incised along the lower margin of the orbit and stripped up from the orbital floor as far as the sphenomaxillary fissure and the posterior end of the infraorbital canal. The orbital margin is now cut through with chisel or rongeur and the roof of the canal removed. The orbital tissues are retracted upward, the nerve separated from the vessels and lifted out of its bed. The nerve is divided and avulsed in both directions. If possible the nerve should be divided in the sphenomaxillary fissure behind the posterior dental branch. This cannot often be done, and an effort must be made to cut off this branch from its central connections by the operation of twisting and avulsion of the root.

However successful this operation may be, there is still apt to remain Meckel's ganglion with its posterior palatine branches, and also the orbital branches. To make the operation complete, it is necessary to resect the nerve at the foramen rotundum.

Division of the second division of the fifth nerve at the foramen rotundum is accomplished through the antrum of Highmore. The same incision is used as for exposing the infraorbital foramen, except that it is made longer, and, if necessary joined by another incision along the side of the nose. The front of the body of the superior maxilla is exposed. A trephine opening 1.25 cm. (½ inch) in diameter is made just below the foramen. The bottom of the canal is chiseled out, and the posterior wall of the antrum opened by a trephine 7 mm. (¼ inch) in diameter. This exposes the sphenomaxillary fossa. The nerve is now isolated, lifted down from its bed, followed back to the foramen rotundum, and cut off with scissors close to the base of the skull. Bleeding should be slight and easily controlled by pressure. A good view should be secured by means of a head light and reflector. Close examination should be made to see that the sphenopalatine branches, passing down to the ganglion, are divided. By cutting all the structures passing through the foramen, these branches will be divided. In doing this the vidian nerve is cut and the facial branches to the palate muscles paralyzed.

Many other operations have been devised for reaching the foramen rotundum. Kocher carried an incision outward and downward across the malar

bone to the lower border of the zygoma. The periosteum and muscles are reflected upward and downward, and the infraorbital foramen exposed. The malar bone is bared within the orbit back to the sphenomaxillary fossa, the malar process of the superior maxillary bone divided, also the zygomatic and frontal processes of the malar, and the malar bone turned upward and outward. This exposes the upper and outer part of the antrum, and the sphenomaxillary fossa (Fig. 680). The nerve can be freed from its canal from below, followed back to the foramen rotundum, divided and pulled out. After the neurectomy the bone flap is replaced and the wound closed.

The inferior maxillary or *third division of the fifth nerve* supplies the lower jaw and lower part of the face. The mental nerve may be reached as it emerges from the foramen in the lower jaw below the second bicuspid tooth by

FIG. 680.—EXPOSURE OF SUPERIOR MAXILLARY NERVE IN SPHENOMAXILLARY FOSSA.

an incision through the mucous membrane below the alveolar process. Division at this point is rarely of much value, as the disease is usually proximal to it.

Division of the nerve as it enters the bone is best accomplished by trephining the ramus. The inferior dental nerve enters the bone midway between the anterior and posterior borders of the ramus, and midway between the sigmoid notch and the lower border of the bone. An incision is made curving around the angle of the jaw, and the skin flap dissected upward and forward. The facial nerve should be avoided. Blunt separation of the fibers of the masseter muscle should be made, and the bone exposed opposite the beginning of the inferior dental canal. The bone is removed by trephine or chisel, the nerve exposed and avulsed (Fig. 681). There is less danger of harming the branches of the facial nerve if the incision is carried down through the periosteum around the angle, and the periosteum and masseter muscle reflected upward.

The nerve may be reached *internally to the ramus* through an incision around the angle of the jaw, downward and forward, carried through the periosteum. Instead of elevating the periosteum on the outer aspect of the ramus, as is done in the above-described operation, the periosteum and

muscle are stripped up from the bone on the inner aspect of the ramus until the nerve is exposed as it enters the canal. The mouth of the canal is marked by a little spine which can be felt with the finger. The nerve can be caught with a hook and drawn down. If it is desired to reach the lingual nerve, it also may be secured through this incision as it comes off a short distance above the inferior dental. The nerve may be pulled down, divided and avulsed. Still better, access may be secured by sawing partly through the angle from within outward and turning it outward as a flap to be replaced at the end of the operation. It is possible to reach the nerve by operating *through the mouth*, making an incision through the mucous membrane along the anterior border of the ramus.

The *lingual nerve* may be reached through the mouth by pulling the tongue to the opposite side, and cutting down upon the nerve opposite the back molar teeth as it makes a ridge between the side of the tongue and the

FIG. 681.—TREPHINE EXPOSURE OF INFERIOR DENTAL NERVE.

ramus of the jaw. The nerve should be sought near the bone. The *auriculotemporal nerve* may be reached as it lies behind and internal to the temporal artery by making an incision parallel to the artery as it crosses the zygoma.

Division of the third division of the fifth nerve at the base of the skull may be made as a part of one of the operations already described for reaching the second division at the foramen rotundum. The two foramina are near together, and if a dry field of operation is secured in a good light, the nerves emerging from each into the sphenomaxillary fossa may be discovered.

The third division may be removed close to the base of the skull by operating *through the deepened sigmoid notch*. A flap is marked out by an incision from the middle of the zygoma backward and downward along the posterior border of the ramus of the jaw. The skin flap is turned forward exposing the connective tissue in which lies the facial nerve. The nerve should be retracted downward. A vertical incision should be carried down to the middle of the ramus of the jaw and the periosteum stripped backward and forward for 2.5 cm. (1 inch) below the sigmoid notch. The trephine is

then applied to the ramus and an opening 2 cm. (¾ inch) in diameter made, leaving a bridge of bone of not more than 6 mm. (¼ inch) between the opening and the sigmoid notch. This bridge of bone is cut away with the rongeur. The condyle and the coronoid process are left attached to the bone (Fig. 682). The inferior dental and lingual nerves are exposed by retracting upward the external pterygoid muscle and exposing the nerves as they lie upon the internal pterygoid. The nerves may be traced up to the foramen ovale and avulsed.

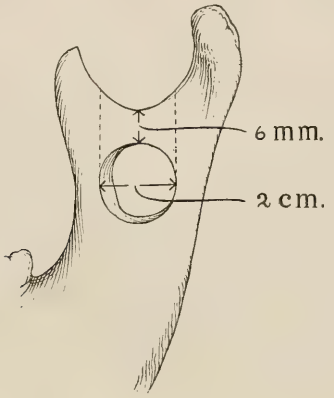


FIG. 682.—EXPOSURE OF THIRD DIVISION OF TRIFACIAL NERVE THROUGH THE RAMUS OF THE JAW.
Showing location of trephine opening.

FIG. 683.—TEMPORARY RESECTION OF ZYGOMA FOR EXPOSURE OF INFERIOR MAXILLARY NERVE.
First step. Incision along zygoma.

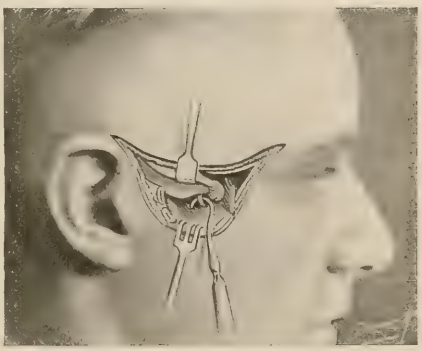


FIG. 684.—TEMPORARY RESECTION OF ZYGOMA FOR EXPOSURE OF INFERIOR MAXILLARY NERVE.
Showing nerve brought outward with a blunt hook.

The third division may be exposed still higher by *temporary resection of the zygoma* (Kocher). An incision is carried from a point just behind the frontal process of the malar bone downward and backward to the posterior extremity of the zygoma, and thence upward and backward to a point above the ear. This is carried through the temporal fascia, down to the periosteum where it crosses the bone, and divides the temporal vessels (Fig. 683). The zygomatic arch is divided anteriorly and posteriorly and retracted downward

with its soft connections. The temporal muscle is separated from the skull in the lower part of the wound and retracted forward. The periosteum and soft parts are elevated from the bone, following the anterior root of the zygoma to the base of the pterygoid process. The foramen ovale is situated about 3 cm. (1¼ inches) internal to the anterior root of the zygoma. The middle meningeal artery enters the spinous foramen just behind it. The internal maxillary artery is retracted downward with the soft tissues into the sphenomaxillary fossa. The nerve, emerging from the foramen ovale can be brought forth with a blunt hook, divided and avulsed (Fig. 684). The resected zygoma is then sutured back in place.

For *exposure of both second and third divisions* of the trifacial nerve, temporary resection of the zygoma and coronoid process is practised by the method of *Krönlein*. An incision carried from the upper border of the

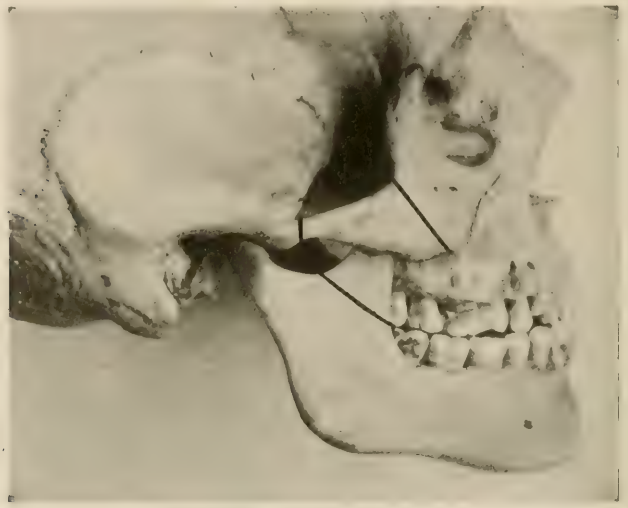


Fig. 685.—Lines of Bone Incisions for Turning Back Flap for Exposure of Second and Third Divisions of Trifacial Nerve.

zygoma, just in front of the ear, downward and curving forward and upward in a U-shape ends at the upper anterior border of the zygoma. A skin flap, superficial to the facial nerve, is turned up; the temporal fascia is divided along the upper border of the zygoma; the zygoma is sawed through in front and behind and retracted downward; the coronoid process is cut through at its base (Krönlein removes it); and the temporal muscle is retracted upward (Fig. 685). The internal maxillary artery is divided, the upper head of the external pterygoid muscle is separated from the great wing of the sphenoid, and the external pterygoid plate exposed (Fig. 685, *A*). The foramen ovale lies just behind this plate, and 3 cm. (1¼ inches) internal to the anterior root of the zygoma. The third division is brought out with a hook. The second division is discovered passing forward to the sphenomaxillary fissure. Each may be divided and pulled out. The zygoma is then sutured back in position.

Conclusions.—Experience is showing that these peripheral operations in trifacial neuralgia major offer too small a proportion of permanent cures to make them well worth while. Recurrence may be expected in most cases. If the neuralgia is of the minor type division of the affected nerve may be

expected to give relief; but if more than two branches are involved recurrence of neuralgia may be expected to follow even division and avulsion below the base of the skull.

The treatment of *tic douloureux* should at first be hygienic and medical. These failing, alcoholic injections should be tried. The excellent results that are being secured with alcoholic injections even in *tic douloureux* and the considerable mortality which still accompanies the intracranial operation indicate that the former should be faithfully tried in most cases before the latter is resorted to. This not giving relief, operation on the Gasserian ganglion promises the best chance of cure. In severe cases the feeling is growing among surgeons that little time should be lost on medical treatment,

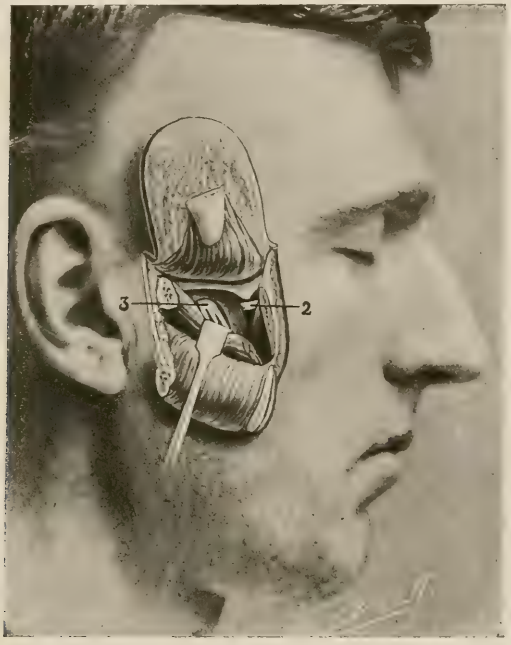


FIG. 685*a*.—EXPOSURE OF SECOND AND THIRD DIVISIONS OF TRIFACIAL NERVE BY TEMPORARY RESECTION OF ZYGOMA AND CORONOID PROCESS.
Showing second division (2) and third division (3).

but that alcoholic injections should be made early, and these failing, excision of the Gasserian ganglion or removal of its sensory root should be done.

Surgeons who are skilled in making alcoholic injections find that they can do with this method all that resection of nerves can accomplish. If the surgeon wishes to act with absolute accuracy the nerve may be exposed by operation and injected by the aid of vision.

Neuralgia of the Facial Nerve.—The facial or seventh nerve, supplying the muscles of the face with motor impulses, receives sensory fibers from the geniculate ganglion through the *pars intermedia* of Wrisberg. Some of the neuralgic conditions of the ear (otalgia) are due to disturbance of the sensory part of this nerve. The facial area commonly affected is the anterior wall of the external auditory canal and the skin just in front of the ear. This area is supplied also by the trifacial nerve, and the mistake should not be made to treat the latter when it is not at fault. When constitutional measures

have failed to give relief, operative treatment is called for. The operation demanded is division of the *pars intermedia* (see Intracranial Operations, Vol. II).

Sciatica.—As in other neuralgias, the cause should be sought and eliminated. In the meantime the thigh should be immobilized with a long side splint, and the patient kept at rest in bed. The bowels should be emptied and a much restricted diet prescribed. Local rest and the elimination of intestinal toxemia will effect a cure in many cases.

Rest and relaxation of the nerve are still better secured with the thigh immobilized in a position of slight flexion, abduction and outward rotation. This position may be maintained with a plaster-of-Paris hip spica. In connection with rest, the induction of local hyperemia is of service. Hot air, hot water, the actual cautery, blisters or hot sand applied to the back of the thigh and pelvis are useful. In the older cases, the galvanic current is used with a large positive electrode over the calf and a negative electrode over the region of the sciatic notch.

Internal medication should aim at the etiologic defect. Iodids, quinin, iron, arsenic and salicylates have their specific values. For other internal medication see Neuralgia (page 862).

In some cases good results have been secured not by rest but by motion and massage from the beginning, anesthetics being used if necessary. This treatment is not to be recommended if the lesion is a neuritis.

Treatment by injections gives so large a percentage of cures that it should not be long deferred if relief is not secured by the more simple means. There are many substances employed. Alcohol is contraindicated because of the liability to produce permanent degenerative changes in the motor fibers of the nerve. *Normal salt solution* has been found most valuable for injection into the substance of the nerve. It is used at body temperature in amounts from 60 to 120 c.c. Schlesinger found an advantage in refrigerated solution, and used normal salt solution at a temperature of 0°C. The cold solution is used in amounts from 10 to 60 c.c. Beta-eucaine or other analgesic may be added to salt solution; but inasmuch as the injections are but slightly painful, as the pain is caused by the prick of the needle and the first pressure of the fluid, and as the therapeutic effect is largely due to the mechanical action of the mass of fluid, the addition of such drugs offers little advantage. The value of the injections seems to be in breaking up intraneural and perineural adhesions. It is for this reason that the larger amounts seem most effective.

The nerve should be injected at one point; and if other injections are required other points should be selected. The place of choice is just below the sacrosciatic foramen. If the needle is inserted at the level of the gluteal fold midway between the tuberosity of the ischium and the great trochanter and passed forward and slightly upward it will strike the nerve. The nerve is about 6 to 7 cm. (2½ to 2¾ inches) from the skin at this point in persons of average build.

A more accurate method is as follows: Let the patient be placed on the well side with the diseased thigh and leg semiflexed. A line is drawn from the sacrococcygeal joint to the outermost prominence of the great trochanter at the postero-external border. This will cross the spine of the ischium at the junction of its inner and middle thirds. The middle of the sciatic nerve is a thumb's breadth (2.5 cm.) external to the spine (Fig. 686). The nerve lies upon the bone at this point. The four points may be marked with tincture of iodin. An anesthetic is rarely required, and then only in very nervous patients.

A sterilizable syringe, capable of holding 20 to 60 c.c. (⅔ to 2 ounces),

with a needle 8 to 10 cm. (3 or 4 inches) in length is used. The needle should be directed slightly upward in order to send the fluid centrally. When the nerve is reached, a sharp pain is felt in the heel or back of the leg, or a dull pain at the knee, thigh or buttock and the leg often jerks involuntarily. The aim is to inject the substance of the nerve. The fluid should be slowly injected. If necessary, without removing the needle, the barrel of the syringe may be detached and refilled.

The neuralgia should be relieved at once. If it is not, subsequent injections may be given. It is customary to wait a day or so between injections. If the nerve has been injected and relief is not secured, it may be assumed that the lesion is higher up. Usually if relief is not secure it may be assumed that the nerve has not been reached or that not enough fluid was used. Some local soreness persists for a few days, and the patient should be kept quiet. No injurious results need be anticipated. Bum reported 62 per cent. of cures; in 20 per cent. of cases there was marked improvement; and in 9 per cent. of cases, no improvement.

Injections of air serve by breaking up adhesions and relieving the nerve. The action is much the same as that of salt solution. A needle, connected by rubber tubing to a syringe or rubber bulb, filled with air which has been filtered through sterile cotton, is passed to the nerve. After introducing the needle the operator should wait to be sure that it has not entered a blood-vessel. Air is injected in several places along the course of the nerve. The injection should be done slowly. The air passes along the sheath of the nerve. It appears under the skin as a pale swelling which later turns red. As much as 300 c.c. of air may be injected in the gluteal region. If precaution is taken to prevent the injection entering a vein, there seems to be no danger. Good results are secured by this method.

The injection treatment is applicable to the lancinating sciatic pains of *locomotor ataxia*. *Fever* sometimes follows the injections on account of the salt in the solution. This may be avoided by neutralizing the salt with calcium chlorid thus: salt 6 parts, calcium chlorid 0.75 parts, water 1000 parts. Hecht places his patients prone with a pillow under the groins. Bum uses the supported knee-elbow position and makes the injection at the point where the long head of the biceps is crossed by the lower border of the gluteus maximus. The treatment should not be applied to acute cases lest neuritis be present. The latter yields best to the rest treatment.

In cases not amenable to the above methods good results have been secured by the use of cocain or other analgesic solutions by *lumbar puncture* into the subarachnoid space of the cord (see Spinal Anesthesia, page 127).

Nerve stretching has proved of much service in obstinate sciatica due to neuritis. "Dry stretching" may be done by flexing the thigh with the leg extended. If there is much pain, a local anesthetic may first be injected. Ten cubic centimeters of salt solution containing 0.03 Gm. (½ grain) of cocain; or more of stovain or eucain, may be used. Massage of the nerve in the gluteal and upper thigh regions at the same time helps to break up adhesions.

Stretching by the open method is more accurate. Under general or local anesthesia, the nerve is exposed just below the lower border of the gluteus maximus muscle. Here it is covered only by the skin and fascia. If the point, described above for injecting the nerve, is taken, it follows a line drawn from this down to the middle of the popliteal space. Or as an upper point may be taken the junction of the middle third and the inner third of a line from the tuberosity of the ischium to the postero-external border of the great

trochanter. A longitudinal incision is made in the line of the nerve, having its middle at the lower border of the gluteus maximus. The biceps muscle will be found at the bottom of the wound, running downward and outward from beneath the transverse lower border of the gluteus. By retracting the biceps inward and the gluteus upward, the nerve is exposed (Fig. 686).

The nerve should be isolated and a pad of gauze wrapped about it. This is grasped by the fingers and traction made in both directions. Trombetta showed that 83 kilos (183 pounds) of force are required to break the nerve. Not more than 14 or 18 kilos (30 or 40 pounds) of traction are required for therapeutic purposes. Too much traction upon the central part may pull it out. The adhesions which it is desired to break up are usually about the sciatic foramen and internal to it.

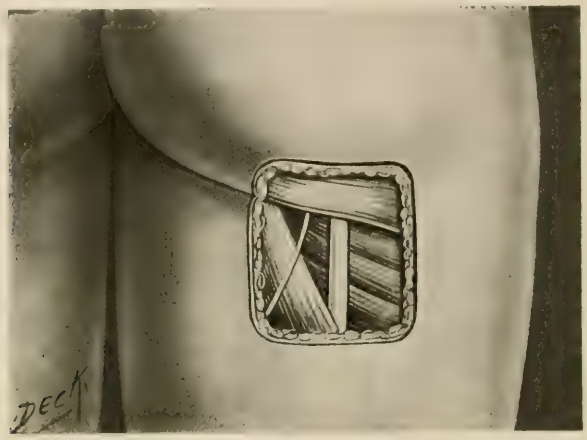


FIG. 686.—GREAT SCIATIC NERVE, SHOWING LOCATION OF NERVE FOR INJECTION.

The great sciatic and the small sciatic are seen emerging from beneath the lower border of the gluteus maximus muscle, the former passes anterior to the biceps muscle and the latter passes superficial to it. The adductor magnus is seen lying in front of the greater nerve.

Higher operations are required in cases not cured by the above methods. It will sometimes be found that the nerve roots as they emerge from the sacral foramina are involved in adhesions. These are the result of old bone, sacro-iliac joint or pelvic disease. To reach the nerve high up, it may be exposed at the sacrosciatic foramen and loosened from adhesions by blunt dissection with the finger. Or the surgeon may make a partial or, if there is disease, complete resection of the sacro-iliac joint, and free the roots from adhesions. Many of the intractable sciaticas are associated with adhesions about the roots of the nerve in the pelvis, and are only relieved by the operations which loosen the nerve from such compression. By exposing the nerve high in the pelvis at the sacral plexus relief may be secured.

Lower operations may be sufficient in some cases of sciatic neuralgia. The *external popliteal* may be reached for saline injection as it curves round just below the head of the fibula.

TUMORS OF NERVES

The tumors involving nerves are true neuromata, amputation neurofibromata, multiple neuromata, fibromata mollusca, plexiform neuromata, tuberculo dolorosa, certain pigmented nevi, sarcomata (primary and secondary),

carcinoma (secondary and by extension), lepra nodules, gummata and tuberculous nodules.

Neuromata if small and giving no symptoms need not be removed. If they show a tendency to continuous enlargement they should be excised through a longitudinal incision. The tumor should be shelled out and the nerve spared as much as possible.

Amputation neurofibromata occur upon the central ends of divided nerves. The more irritation there is in the wound or to the nerve end, the greater the liability to this bulbous swelling. In amputation stumps the nerve should be protected from irritation by pulling it down and cutting it high above the wound. When stumps require to be operated upon because of painful nerve ends, secondary neurofibromata or neurofibromatous degeneration may exist above the terminal tumor. This should be looked for, and the nerve divided above such neoplasmic conditions.

The tumors of nerves, for therapeutic consideration, may be divided into (1) those which give no symptoms, (2) those which give symptoms, and (3) those which are malignant. The first class requires no treatment excepting where their removal is demanded, for cosmetic reasons. The symptoms calling for operative relief are pain, paralysis, paresthesia, spasm, contractures and mechanical interference with fnuction because of the size of the tumors. Malignant tumors of nerves should be removed. Benign neurofibromata are prone to undergo malignant changes and become sarcomatous, for which reason their removal is always to be considered. In all operations upon tumors of nerves the nerve should be saved if possible. Often it will be found that the nerve fibers are spread apart and the tumor can be removed without destroying the continuity of the nerve. In other cases, after removal of the tumor with a segment of the nerve, an operation for nerve bridging may be done.

INJURIES AND DISEASES OF SPECIAL NERVES

The Fifth Cranial Nerve.—This nerve has been considered under Neuralgia (page 865). The treatment of its injuries is not peculiar. Herpes zoster, resulting from disease of its roots, requires the treatment of herpes, such as is described with diseases of the skin, and treatment of the trunks, such as is described with neuralgia. The supra-orbital, infra-orbital and inferior dental branches are frequently injured by fracture-producing violence or other traumatisms. They should be liberated from pressure and adhesions. Operations upon the areas supplied by this nerve may be done after injecting the nerve or its branches with novocain solution. The injections are made by the same technic as for the treatment of neuralgia.

The Facial Nerve.—This nerve is often inflamed and injured to the degree of causing paralysis or convulsive irritability. It is extremely susceptible to neuritis which causes paralysis. In fractures of the base of the skull and as a result of injuries to the trunk after it emerges from its bony canal it may require treatment for complete or partial division or for scar involvement. A study of the anatomy of this nerve makes the task of locating the seat of injury or disease one of the satisfying pleasures of surgery.

Neuropathic paralysis of the facial nerve (Bell's palsy) may be temporary or of permanent nature. The cause should be searched for and removed. If the electric excitability remains present the treatment should be removal of the cause, and the application of such constitutional treatment as is applied to neuritis or neuralgia. The bowels should be emptied and toxic absorption reduced to the minimum. The diet should be meager.

Local hyperemia should be increased by the use of hot applications over the course of the nerve. Pressure upon the neck sufficient to cause some jugular obstruction may be of service. After the reaction of degeneration has appeared in a week or more the galvanic current should be used for five minutes daily. The anode should be applied over the nerve just in front of the mastoid process under the ear, and the cathode over the same region on the sound side or at the back of the neck. The amount of current must be regulated to the individual case. It should not be so strong as to cause pain or vertigo. As soon as electric excitability has begun to return, the faradic current should be used on the nerve and muscles of the face together with massage. The prognosis in most cases is good. If there is no loss of electric excitability, recovery may be expected to take place in from two to four weeks. The average time required for recovery is four or five months. If the reaction of degeneration is well marked, recovery may be slow and incomplete. In some such cases the paralysis may remain permanently with little or no abatement. In a few exceptional cases recovery has taken place after many years of palsy.

Much can still be done for cases in which the paralysis remains nearly or quite complete. The nourishment and suppleness of the facial muscles should be maintained by massage and faradic electricity applied daily. Any ear disease which is amenable to treatment should be corrected. If after six months the paralysis remains and the reaction of degeneration is well marked, nerve grafting is indicated.

Nerve Grafting for Facial Paralysis.—If the paralysis of the facial nerve is due to traumatic division of the nerve, it should be sutured as early as possible. If suture has not been applied and the nerve-ends are involved in scar tissue or if there has been loss of substance so that the ends cannot be brought together, the facial does not lend itself well to secondary operations for its repair. In these cases and in the cases of paralysis following neuropathic changes, nerve grafting offers the best hope.

Central impulses may be conveyed into the paralyzed facial nerve either by grafting into it the spinal accessory nerve or the hypoglossal nerve.

Of these two, the *spinal accessory* is most easily reached and the operation is most easily carried out. The spinal accessory is not an important nerve. Its division results in a temporary inability to raise the arm above the horizontal, and some dropping of the shoulder. The trapezius and the sterno-mastoid muscles become partially paralyzed. The chief objection to its use for this operation, whether it is divided or only a slip taken from it, is that, after nerve union has taken place, there is a pronounced and uncontrollable tendency for the facial muscles to contract when the shoulder is moved. There is also a tendency for the shoulder to move when the facial muscles contract. This is because the cortical center of the accessorius is also the center of other muscles which move the shoulder, and when impulses go out from this center to move the shoulder they also pass down the accessorius through its new path to the facial muscles and cause their simultaneous contraction. Persons under middle age can educate the muscles to overcome this; in older persons it is apt to be a permanent disability.

The use of the *hypoglossal nerve* for this purpose has the advantage that its cortical centers are near those of the facial and consequently act more in unison. Division of the hypoglossal destroys the motor function of half of the tongue and results in its atrophy, but its division is not necessary. Not enough of either of these operations have been done to determine which is best. At present surgeons are divided in their preferences, the preponderance of favor being for the hypoglossal-facial grafting. Whichever nerve

is used the impulses of the whole nerve are necessary to secure anything like a normal restoration of function in the facial muscles.

The results of both operations leave much to be desired. Return of function is slow; and, because of the delicate shades of expression normally residing in the facial nerve, a complete restoration of function is not to be expected. But even the least enervation of the facial muscles is a great help, and to have some return of tone changes them markedly. Many months may elapse after operation before results are observed. In the mean-

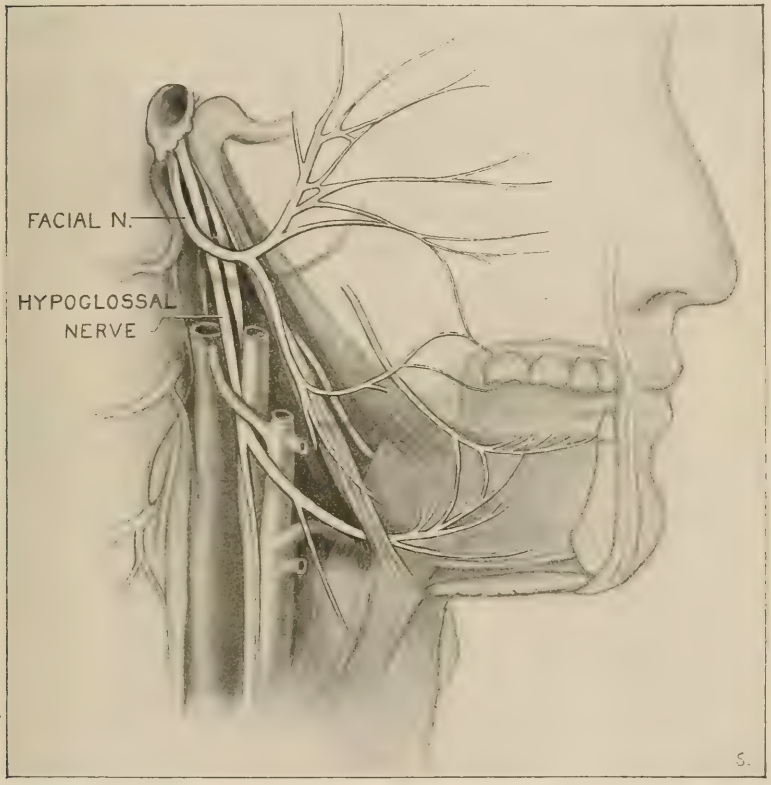


Fig. 687.—Showing Relations of Hypoglossal and Facial Nerves.

time the nourishment of the muscles must be kept active by the use of faradism. Several years may elapse before improvement ceases.

Hypoglossal-facial Nerve Grafting.—An incision is made from a point behind the ear on a level with the external auditory meatus downward along the front of the mastoid process and the anterior border of the sternomastoid muscle as far as the level of the thyroid cartilage. The parotid gland with its capsule is drawn forward, and the sternomastoid muscle backward. The styloid process is felt for. This is the guide to the facial nerve which emerges from the stylomastoid foramen between this process and the mastoid process, and passes directly forward below the external auditory meatus close to the bone (Fig. 687). The nerve is isolated with as little traumatism as possible, and divided with a sharp knife close to the bone.

To expose the hypoglossal nerve, the transverse process of the atlas is felt for. The deep fascia should be incised in front of this process. The internal jugular vein is exposed, and should be retracted forward. Beneath the vein appear the pneumogastric nerve and the hypoglossal nerve. They should be differentiated by applying gentle stimulation. Stimulation of the pneumogastric causes slowing of the heart. Stimulation of the hypoglossal causes contraction of the tongue muscles, the sternothyroid, thyrohyoid, and geniohyoid muscles.

The nerve having been identified, it is freed from its bed without dividing its branches communicating with the pneumogastric. A slit is made in it to receive the stump of the facial, which should be curved around to reach

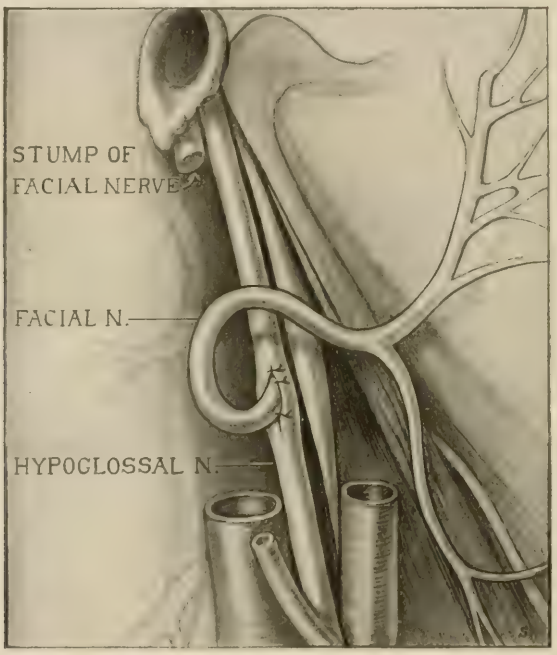


FIG. 688.—FACIOHYPOGLOSSAL IMPLANTATION.
The facial nerve has been divided near its exit from the skull just below the external auditory meatus, and the distal end implanted in the hypoglossal nerve.

it without tension (Fig. 688). The facial should be sutured in such a way that, as it leaves the hypoglossal, it should pass downward. Fine well-chromicized catgut should be passed with a fine needle through the sheath of the hypoglossal into the wound, thence through the sheath of the facial, and then through the sheath of the hypoglossal on the other side of the wound. One of these sutures may be applied above and one below (see Suture of Nerves, pages 853 and 860).

If the facial is too short for the above operation the hypoglossal may be split and a segment swung around to meet the facial (Fig. 689). A cuff of fascia or other tissue should be sewed around the union so that it lies in a tube.

If the surgeon cares to sacrifice the distribution of the hypoglossal, it may be cut as far forward as possible, the proximal stump swung around

the posterior belly of the digastric muscle, and united to the distal stump of the facial nerve (Fig. 690).

Accessorius-facial Nerve Grafting.—The spinal accessory may be exposed through the above incision. The nerve emerges from the skull by the jugular foramen, passes over the transverse process of the atlas, and enters the substance of the sternomastoid muscle about 5 cm. (2 inches) below the tip of the mastoid process. As the nerve passes down from the transverse process of the atlas it lies behind the deep fascia and is covered by the posterior belly of the digastric (Fig. 691). The distal portion of the divided facial must be connected with it in such a way that its impulses shall be conveyed into the facial. This is best accomplished by dissecting free the accessorius for a

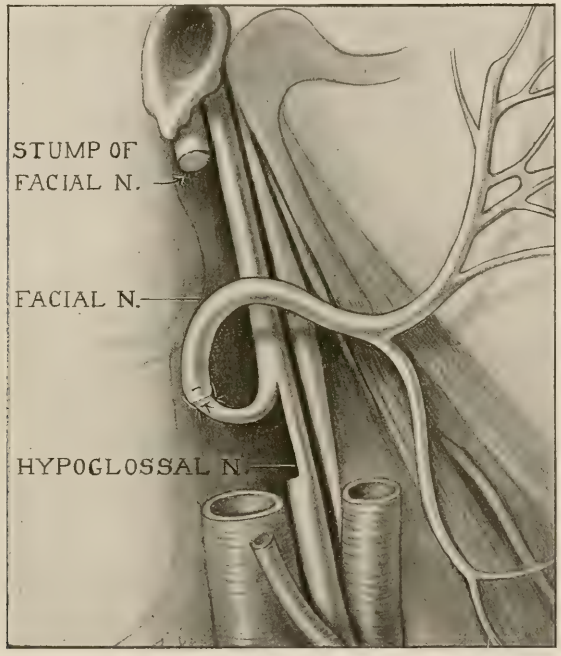


FIG. 689.—FACIOHYPOGLOSSAL ANASTOMOSIS.

This operation is indicated when the facial nerve is too short for implantation in the hypoglossal trunk. A slip is cut from the hypoglossal and united with the facial.

distance sufficient to allow its stump to be brought in apposition with that of the facial, and dividing the nerve. It is best to pass the two sutures through its sheath before cutting it. The proximal stump is then sewed end to end to the facial. The finest well-chromicized catgut should be used. Many surgeons prefer fine silk. Suture of rat-tail tendon is, perhaps, preferable to either (Fig. 692).

Instead of dividing the nerve, the branch to the trapezius alone may be used for grafting, or the nerve may be split above its division and a slip carried to the facial. It is important that there shall be no tension at the place of suture. This may sometimes be facilitated by carrying the nerve internal to the digastric. Division of the digastric is not to be recommended because the production of scar tissue must be minimized in every way if the operation is to succeed.

Hypoglossal-accessorius-facial Nerve Grafting.—This operation consists in uniting the facial to the spinal accessory, and then uniting the peripheral stump of the spinal accessory to the descending branch of the hypoglossal. The operation is carried out by the same steps as above described. Each of the three nerves is isolated, and a silk loop thrown about it for identification. The posterior belly of the digastric may be divided temporarily just behind its tendon. The distal stump of the facial is made as long as possible.

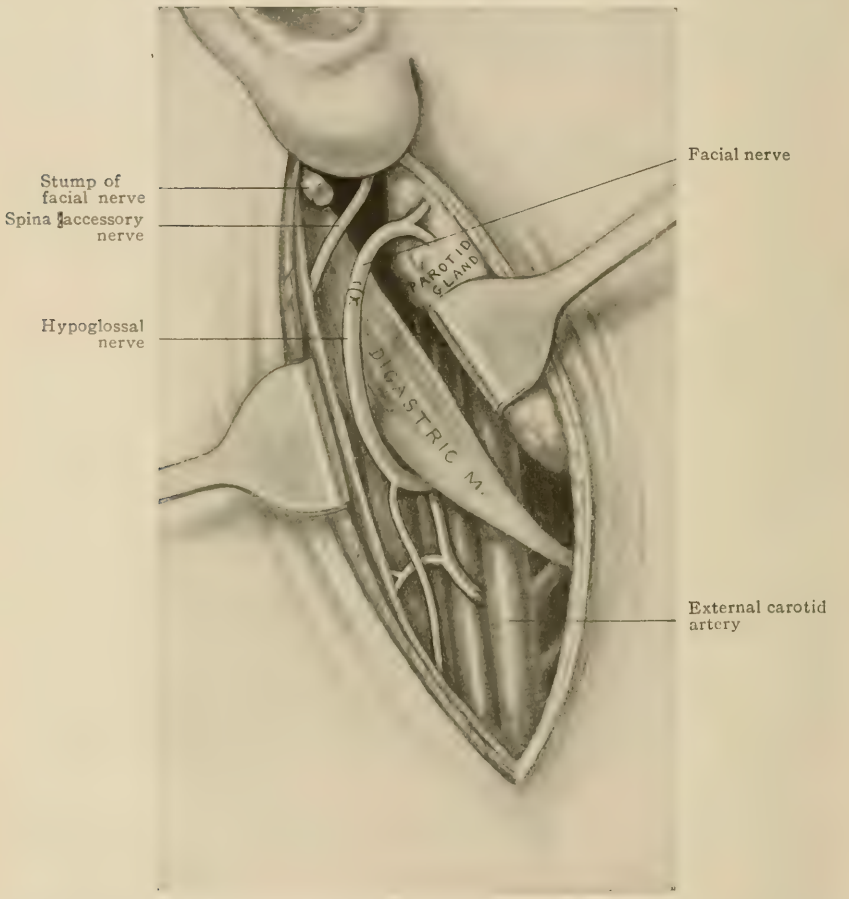


FIG. 690.—FACIOHYPOGLOSSAL ANASTOMOSIS.

The hypoglossal and facial nerves both are divided and the proximal stump of the hypoglossal united with the distal stump of the facial. This operation destroys the natural supply of the hypoglossal.

If the nerve is intact it should be dissected free as far as the stylomastoid foramen and there divided. The accessorius is then divided at its entrance into the sternomastoid muscle, and the proximal stump sutured to the facial as above described. The descendens hypoglossi is a slender branch which passes down from the hypoglossal as the nerve curves round the occipital artery. It passes down over the carotid sheath to the muscles of the neck. The nerve is given off from the hypoglossal where the latter lies on the hypoglossus muscle and is covered by the posterior belly of the digastric or

by the digastric tendon. The descendens is cut in two fully 2 cm. (¾ inch) below its origin from the hypoglossal. Its proximal end is carried up and sutured to the peripheral stump of the divided spinal accessory (Fig. 693). The unions should be wrapped about with fascia, the belly of the digastric sewed, the wound closed and the head immobilized. The object of this operation is to preserve the nerve supply of the accessorius to the trapezius and sternomastoid muscles.

Other Operations.—Ballance made an end-to-end anastomosis between the facial and hypoglossal nerves, and then split the spinal accessory nerve,

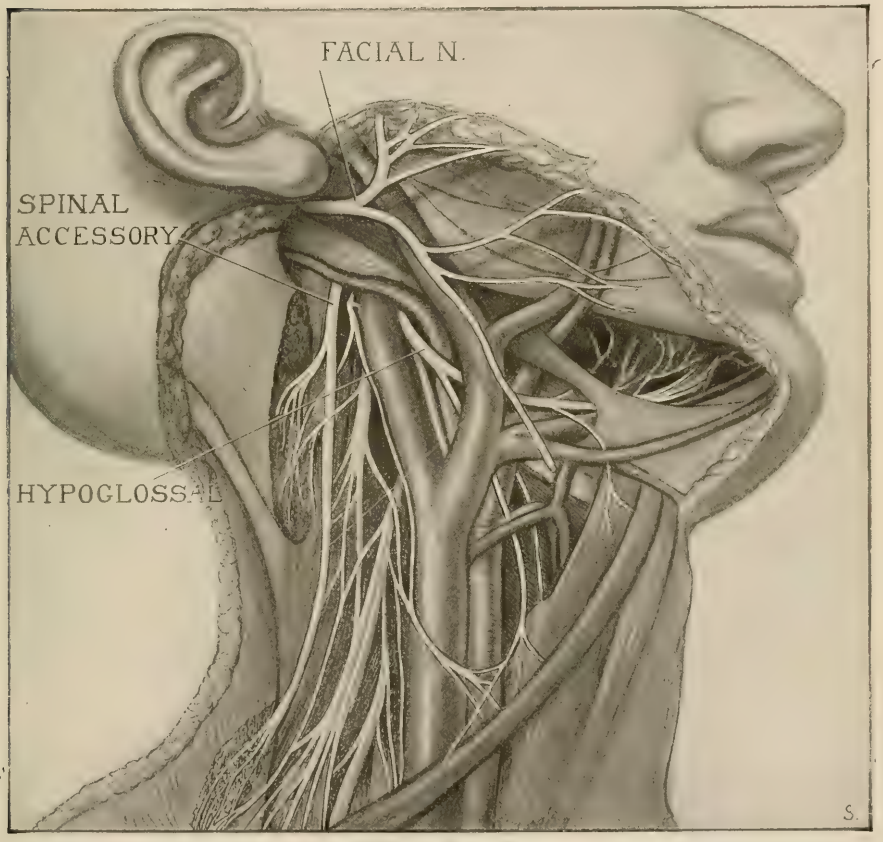


Fig. 691.—Relations of Spinal Accessory, Facial and Hypoglossal Nerves.

and sutured the split off half to the distal end of the hypoglossal. By keeping closely to the sheath of the sternomastoid muscle, the parotid gland is not disturbed. The spinal accessory is over, or just below, the tip of the transverse process of the atlas. The hypoglossal nerve passes just beneath the tip of the atlas and runs parallel with the posterior belly of the digastric muscle. The anastomosis may be embedded in the substance of the sternohyoid muscle. About six months is the average time which elapses after the operation before return of motion is observed.

The results of these operations have been most gratifying when performed by skillful operators. After the wounds are healed electric current should

be applied to the muscles; also massage to the neck and face. The faradic current should first be used, and this should be followed by galvanism as soon as the paralyzed muscles begin to respond. After a period of three or four months the patient becomes conscious of returning muscular power.

Only when the whole supply of the nerve runs into the facial is a result secured which restores anything like the normal expression of the face. This means that the hypoglossal or accessorius, whichever is used, must be divided. But, however, much restoration of the facial function is secured. It is worth trying for.

Spasm of the Facial Muscles (*Tic convulsif*).—This condition should be treated by attention to the general health. The cause should be sought

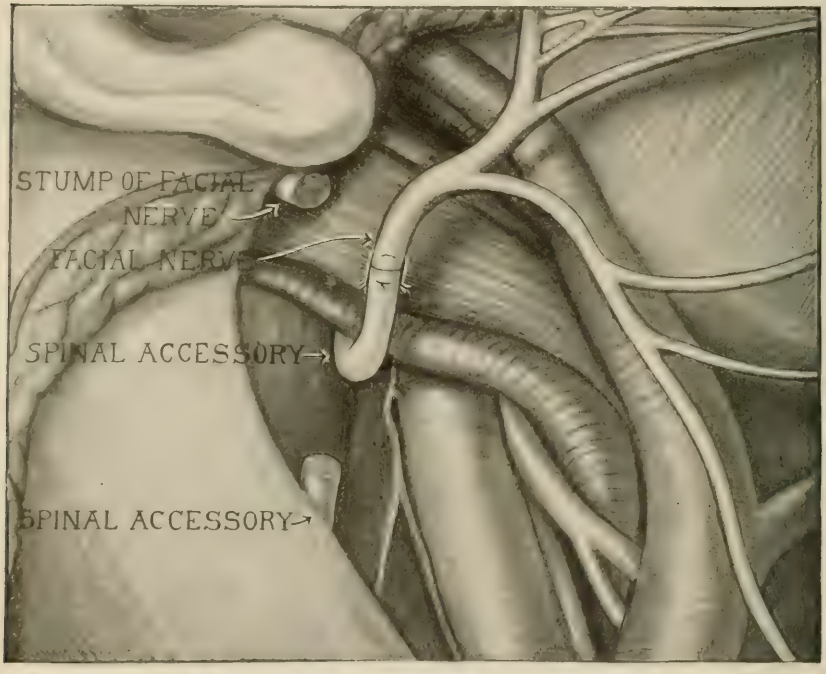


FIG. 692.—ACCESSORIUS-FACIAL NERVE ANASTOMOSIS.

Showing facial nerve divided close to its exit from the skull, spinal accessory divided near its entrance into the sternomastoid muscle, and the proximal stump of the latter united to the stump of the former.

and if possible removed. The same conditions which produce neuralgia of the third nerve should be sought. Eyestrain should be eliminated. The teeth and nose should be seen to. Diseases in remote organs should be cured. In some cases some pathologic condition can be found within the facial zone which is responsible for the irritation of the nerve. In most cases nothing of the sort can be discovered. The mental state should be made as nearly normal as possible; fatigue, excitement and worry should be eliminated; and the use of drugs, such as are found in tea, coffee, tobacco, liquor, etc., stopped.

Galvanism, applied as in facial palsy, is of service in many cases. The injection of the nerve with alcohol (1 or 2 c.c. of a 70 per cent. solution) gives relief by paralyzing the muscle. The injection should be made into the nerve

at the stylomastoid foramen. The injection causes complete facial paralysis, which lasts for several months. In cases thus treated the spasm often does not return after the nerve resumes its motor function. If the spasm does return it is not until weeks or possibly years after the function of the muscle returns. This treatment should supersede the operation of division of the nerve.

The needle used for injection should be about 10 cm. long and 0.4 cm. thick, and marked in centimeters. The best form of needle is a trocar with a stilette. The skin at the angle of the jaw is painted with tincture of

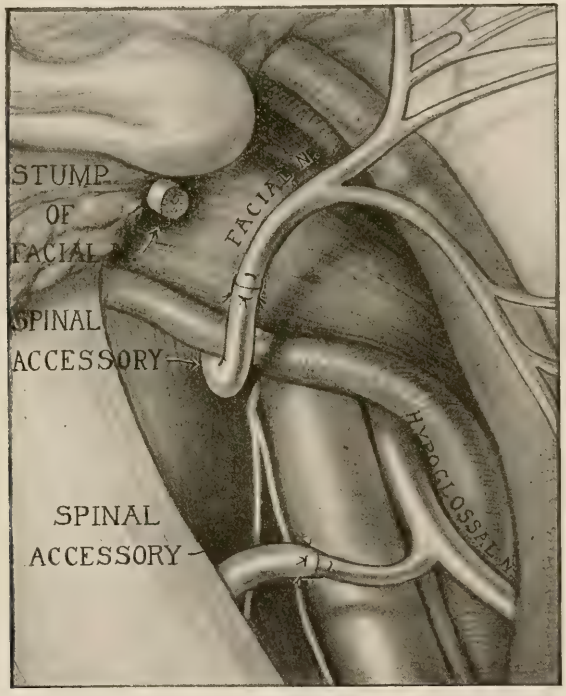


FIG. 693.—HYPOGLOSSAL-ACCESSORIUS-FACIAL NERVE ANASTOMOSIS.

The facial nerve has been divided close to its exit from the skull; the spinal accessory has been divided just above its entrance into the sternomastoid muscle, and the two have been united as for accessorius-facial anastomosis. The descending branch of the hypoglossal nerve has been divided and its proximal stump united with the distal stump of the accessorius. This operation restores the function of the facial and preserves the function of the accessorius by sacrificing the unimportant descending branch of the hypoglossal.

iodin and injected with 1 per cent. novocain. The needle is passed backward and upward until it strikes the base of the mastoid process. Then the needle is slightly withdrawn and the point is carried inward, feeling its way until it strikes the stylomastoid foramen. The stilette should be withdrawn. If blood flows, the needle should be withdrawn and entered in another place. The usual depth the needle passes is about 5 cm. If there is no bleeding a little of the alcohol should be injected. If the nerve is reached, immediate paralysis of the facial muscle takes place. The rest of the alcohol is then injected, and the needle removed.

If there is pain it may be relieved by hot applications. The patient

should wear goggles to protect the eye from dust, and the eye should be washed out several times daily with borax solution, because of the fact that the winking muscles are paralyzed and the cornea becomes dry. It is well for the patient to press the two eyelids together frequently with the fingers. The face should be massaged twice daily to preserve the muscles.

The result of the operation is that the patient exchanges a spasm for a paralysis. If the spasm recurs the injection may be repeated.

Nerve stretching has cured a small proportion of the cases in which it has been tried; it has given improvement in about one-third of the cases; but most have not been helped by it. It is always worthy of trial.

Grafting with the hypoglossal or spinal accessory, as for facial palsy, is the treatment which offers the best hope for relief if the other methods have failed. This has been done successfully by Kennedy, Cushing and others.

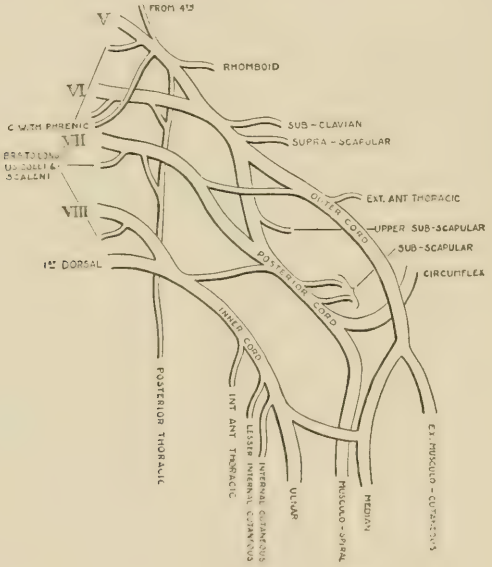


FIG. 694.—BRACHIAL PLEXUS.

Neuralgia of the Facial Nerve.—(See page 877.)

The Auditory Nerve.—Disturbances of this nerve are often associated with disturbances of the facial. This is especially the case when due to fracture of the base of the skull. Persistent *tinnitus aurium*, vertigo, and other annoying symptoms arising from disturbances of the auditory nerve, which resist hygienic treatment and other local measures, have been relieved by division of the nerve (see Intracranial Operations, Vol. II).

The Spinal Accessory Nerve.—Disease or injury, causing paralysis of this nerve, produces the symptoms already described (page 885). Its accidental division should be repaired because of this and because of the possibility of paralytic torticollis. Spasmodic torticollis, due to accessorius irritation, often requires stretching or division of the nerve (see Torticollis, Vol. II).

The Cervical Nerves.—*Cervico-occipital neuralgia*, occurring in the four upper cervical nerves, should receive the general treatment laid down for neuralgia. When not relieved the roots should be exposed and injected

with alcohol. If the neuralgia continues, the posterior roots may be divided within the spinal canal.

The **phrenic nerve** when divided causes paralysis of half of the diaphragm. Although this is not a fatal injury, or even one of gravity, still it is of sufficient importance to call for suture of the nerve if the injury is accessible.

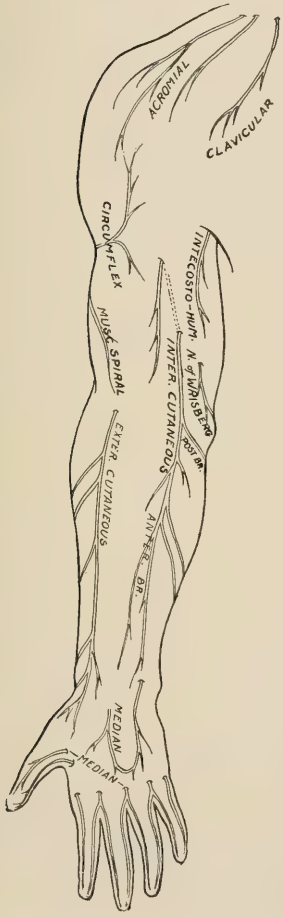


FIG. 695.—CUTANEOUS NERVES OF RIGHT UPPER EXTREMITY.
Anterior view.

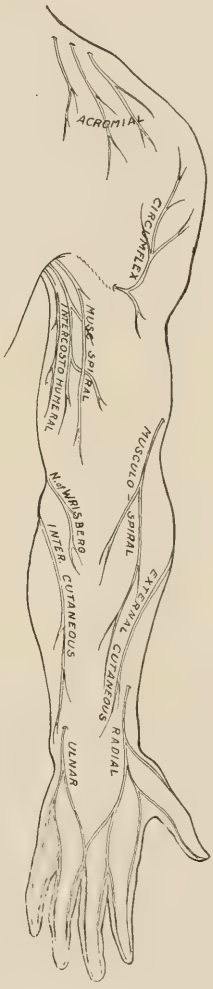


FIG. 696.—CUTANEOUS NERVES OF RIGHT UPPER EXTREMITY.
Posterior view.

The **pneumogastric nerve** is sometimes injured, cut or ligated in operations in the neck. Paralysis of one nerve is not of grave importance. There is apt to be transitory disturbance of the pulse, but one vagus alone seems able to supply the necessary innervation. *Irritation* of one vagus by contusion or wound may supply sufficient stimulus to cause cardiac or respiratory paralysis. Injury of both vagi is serious. Simultaneous division or

paralysis of both is usually fatal. Few of the cases in which one vagus has been divided, clamped, or ligated, are fatal. The danger is so slight that there should be no hesitation in resecting one vagus when the removal of malignant growth requires it.

The **recurrent laryngeal nerve** is liable to injury in operations in the neck. It is jeopardized especially in tying the inferior thyroid artery and in thyroidectomy (*q.v.*). Its paralysis produces palsy of the vocal cord which it supplies. Paralysis of both nerves produces palsy of the glottis, which is fatal unless immediately relieved by tracheotomy or intubation of the larynx.

The **hypoglossal nerve** when paralyzed causes atrophy of half of the tongue. This is not a serious condition but it is of sufficient importance to demand suture of the nerve when divided. Either primary or secondary suture may be done successfully.

The Brachial Plexus.—The roots, cords and nerves of the brachial plexus are subject to all of the diseases and injuries which befall other nerves. The surgeon is concerned particularly with the paralysis due to injury. These injuries may occur at the spine (in dislocations and fractures), in the neck, between the clavicle and first rib, as the nerves pass across the shoulder-joint, or in the arm. Wounds, contusions and stretching are the common etiologic factors. The treatment of these conditions should not be undertaken without a clear conception of the anatomy of the brachial plexus (Figs. 694, 695 and 696). The following table shows the origin and distribution of the nerves of the brachial plexus to the muscles (table after Clark, Taylor and Prout: Am. Jour. Med. Sciences, Oct., 1905; Keen's Surgery, Vol., ii, page 734).

Muscles Moving Scapula and Arm

Muscle	Nerve plexus division	Root origin
Trapezius	Spinal accessory	C. II to VI.
Rhomboideus	Spinal accessory	C. IV and V.
Levator angulæ scapulæ	Spinal accessory	C. III, IV and V.
Serratus magnus	Posterior thoracic	C. V, VI.
Deltoid	Circumflex (posterior cord)	C. IV, V.
Supra- and infraspinati	Suprascapular	C. IV, V.
Teres minor	Circumflex	C. V.
Subscapularis	Short subscapular	C. V, VI.
Latissimus dorsi	Long subscapular (posterior cord)	C. VII.
Pectoralis major	Anterior thoracic (outer and inner cords)	C. V, VI.
Teres major	Suprascapular (posterior cord)	C. VI, VII.

Muscles Moving Forearm

Triceps	Musculospiral (posterior cord)	C. VI, VII.
Brachialis anterior	Musculospiral and musculocutaneous (outer and posterior cords)	C. V, VI, VII.
Biceps	Musculocutaneous (outer and posterior cords)	C. V, VI, VII.
Brachioradialis (supinator longus)	Musculospiral (posterior cord)	C. V, VI, VII.
Supinator brevis	Musculospiral (posterior cord)	C. V.
Pronators (teres and quadratus)	Median (outer and inner cords)	C. VI, VII.

MUSCLES MOVING THE HAND

Flexors of Wrist

Flexor carpi ulnaris	Ulnar (inner cord)	C. VIII, D. I.
Flexor carpi radialis	Median (outer and inner cords)	C. VII, VIII.

Extensors of Wrist

Extensor carpi radialis longus, Extensor carpi radialis brevis, Extensor carpi ulnaris	Musculospiral (posterior cord)	C. VI, VII.

Extensors of Fingers

Extensor communis digitorum, Extensor indicis, Extensor minimi digiti	Musculospiral (posterior cord)	C. VI, VII.

Flexors of Fingers

Flexor sublimis	Median (inner and outer cord)	C. VII, VIII.
Flexor profundus	Median and ulnar (inner and outer cord)	C. VII, VIII, D. I.
Interossei and lumbricales	Ulnar (inner cord)	C. VIII, D. I.
Two outer lumbricales	Median (inner and outer cord)	C. VIII, D. I.

Following injury, if the reaction of degeneration is present after ten days, operation should be done. The nerve may be expected to be found to need suture or anastomosis. Rupture of the cords of the brachial plexus calls for immediate operation and suture. When the trunks are ruptured close to the foramina, a nerve from the sound brachial plexus may be carried across and anastomosed to the torn trunks. This was first suggested by Alexinsky (Chirurgia, vol. vi, 1899). The trunk may be carried across in front of the trachea. It would seem to me that a more satisfactory path would be to remove a spinous process, wrap the nerve in a tube of fascia, and carry it posteriorly.

For the general principles of the treatment of contusions, compression, wounds, neuritis, and paralyses see page 850 *et seq.* The prognosis in these cases depends upon the nature and extent of the lesion. Six to ten months may be allowed in doubtful cases for the return of function. Mild paralyses due to slight pressure or stretching will recover in a few hours or days. Neuritis added to a paralyzing wound gives a bad prognosis. By determining the electric reaction the status of degeneration and regeneration can be determined. The paralyzed parts should be kept healthy by massage, passive motion and electricity.

Mild cases of palsy should have simply this latter treatment daily. Neuritis demands rest until it has subsided. In injuries in which it is known that the nerve has been divided, suture should be done. If the injury is associated with an infected wound, secondary nerve suture is called for. If the symptoms of division of nerve are present, the nerve should be exposed at once. When the muscles respond to faradism and show a tendency to improve, operation is not indicated.

To expose the brachial plexus the patient should lie on the side, and incision should be carried from a point on the posterior border of the sternomastoid muscle, at the junction of its middle and lower thirds, downward and outward to the junction of the middle and outer thirds of the clavicle. This should divide skin, platysma, and deep fascia. The omohyoid muscle should be retracted downward or divided. The suprascapular vessels are

encountered just above the clavicle and retracted downward. The deep fascia overlying the plexus should be dissected away. The plexus is found lying behind the scalenus anticus muscle. Posteriorly is the scalenus medius. The phrenic nerve courses down in front of the former muscle. The plexus passes down behind the clavicle (Fig. 697).

When the lesion is in the lower part of the plexus, below the sixth cervical root or is in the more distal cords, a lower operation must be done. The incision should be extended downward and outward and the clavicle and subclavius muscle divided. At the end of the operation the clavicle is sutured back in place with chromic gut sutures through the periosteum (Fig. 698).

It is most important that the preliminary examinations should have put the surgeon in possession of a pretty accurate knowledge of the location of

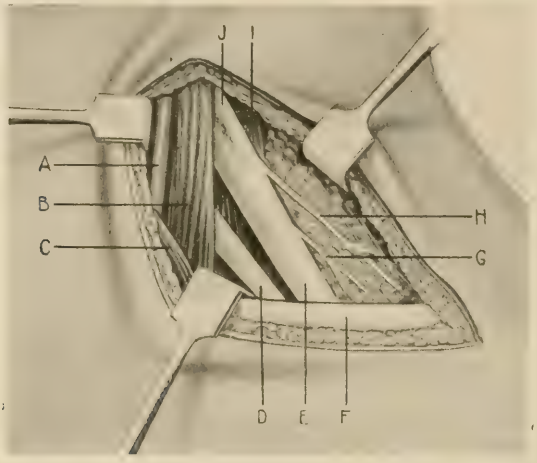


FIG. 697.—BRACHIAL PLEXUS EXPOSED IN OPERATIVE FIELD ABOVE CLAVICLE.

A, Internal jugular vein; *B*, scalenus anticus muscle; *C*, omohyoid muscle; *D*, VII cervical root; *E*, trunk formed by union of V and VI cervical roots; *F*, clavicle; *G*, nerve to subclavian muscle; *H*, suprascapular nerve; *I*, scalenus medius muscle; *J*, V cervical root.

the injury, so that he shall know what he is to look for. Often in recent cases the nerve will be found thickened at the place of injury. A longitudinal incision into this swelling will show it to be made up of the products of exudate which had been poured out between the separated nerve ends. In older cases a swelling will often be found due to neurofibromatous hyperplasia of the proximal stump. The plexus having been exposed, the injured nerve is given the attention which it requires (see Nerve Suture, page 852). The head, shoulder and arm should be put in a dressing to prevent motion after suture of a cord of the brachial plexus. For this purpose a light plaster-of-Paris or starch bandage should hold the head flexed laterally toward the wound, and the arm should be bandaged to the chest. This immobilization should be continued for two weeks. The treatment of paralyzed muscles by massage and electricity should be continued. These operations have given very satisfactory results. The nerves are large, and suture is easy. Improvement often continues for a number of years.

Brachial birth palsy, caused by overstretching the nerves by lateral flexion of the head and traction on the shoulder, may be due to injury which is susceptible of spontaneous recovery. In other cases the nerve is torn apart

to a degree incompatible with recovery without operation. The degree of injury can not easily be determined in infants. Most surgeons prefer to wait until the child is larger before operating. By so doing the nature of the injury may be more accurately determined, the structures are larger, there is less danger from shock and hemorrhage, and spontaneous recovery has been given an opportunity. A delay of a year is advised by Taylor. Cases of over ten years' standing have been successfully operated upon. Cases in which the surgeon can be sure that division of nerve has occurred should be operated upon sooner. Cases in which improvement is taking

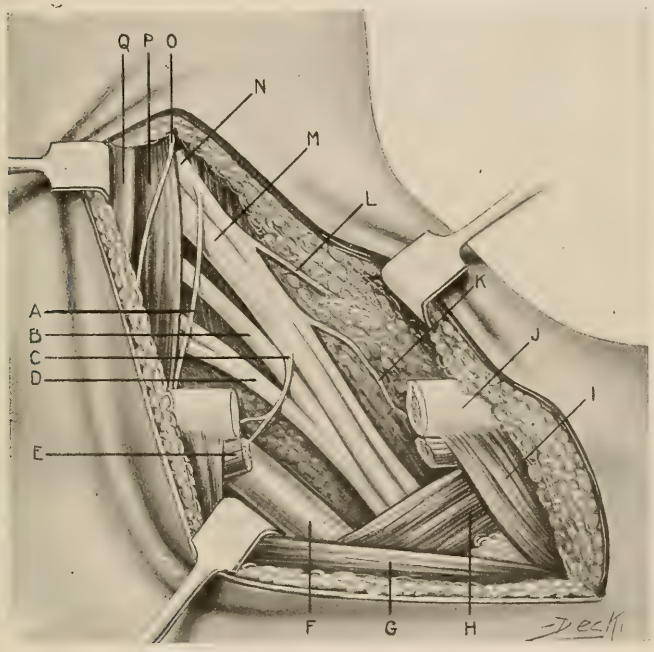


FIG. 698.—BRACHIAL PLEXUS IN OPERATIVE FIELD.

Clavicle resected to expose lower part of plexus. *A*, Nerve to scalenus anticus muscle; *B*, VII cervical root; *C*, external anterior thoracic nerve; *D*, trunk formed by VIII cervical and I dorsal roots; *E*, subclavius muscle; *F*, subclavian artery; *G*, pectoralis major; *H*, pectoralis minor; *I*, deltoid; *J*, clavicle; *K*, nerve to subclavius muscle; *L*, suprascapular nerve; *M*, VI cervical root; *N*, V cervical root; *O*, phrenic nerve; *P*, scalenus anticus muscle; *Q*, internal jugular vein.

place even at the end of a year may be deferred still longer. When the nerves are found involved in a mass of scar tissue, the mass should be excised if the nerves cannot be dissected free. Union by nerve bridging up to 2 cm. ($\frac{3}{4}$ inch) has been secured (see Injuries of the Newborn, Vol. III).

Narcosis paralyses of the brachial plexus occur when patients are unconscious, usually during prolonged operations, especially when the arm is abducted and the head laterally flexed. They are similar to paralyses produced by traction or pressure upon the nerves in any condition associated with unconsciousness or loss of sensory reflexes. Without treatment a return of function may be expected. Usually improvement begins early. In some cases several months may elapse before complete recovery. If recovery is delayed beyond six months, examination for degeneration should

be made; and if complete paralysis is found, the injured nerve should be exposed by operation.

Brachial neuralgia, involving the branches of the brachial plexus, is usually due to constitutional defects, and should receive the constitutional treatment of neuralgia (page 862). Hot applications, massage, vibratory massage, and electricity, applied to the painful area, are of service. Rarely is the cause one of purely local origin requiring operative exposure. Isolated neuralgia of the ulnar, musculospiral, median, or other nerves, requires the same treatment.

Traumatic brachial neuralgia, due to rupture of the brachial plexus, must be treated by the methods applicable to rupture of the nerves. When the neuralgia is intractable and due to injury in the roots of the nerves, the affected posterior roots should be divided inside of the spinal canal. This is done by laminectomy and opening the dura. Patients with these injuries should not be permitted to drag on with their suffering, when relief can be had by this operation (see Spine, Operations on Posterior Roots of the Cord, Vol. II).

Injuries to the Nerves of the Upper Extremities.—The important nerves which are most frequently injured are the great branches of the brachial plexus supplying the shoulder and arm. Diseases and injuries of these nerves require the treatment which has already been given for nerves in general. There are some special considerations. All of these nerves when divided should be sutured. The results are good. When the reaction of degeneration is present, showing non-conductivity, the nerve should be exposed and its injury dealt with.

The **circumflex nerve** supplying the deltoid muscle, is best reached by the incision which is used for exposure of the axillary artery. The nerve passes behind the artery in company with the posterior circumflex, at the lower border of the subscapularis. It passes through the quadrilateral space bounded by the teres major, scapula, long head of triceps, and the humerus.

The **long thoracic nerve** is reached by the incision used for exposure of the axillary artery. The dissection is carried back to the serratus magnus, and the nerve is seen passing posterior to the cords of the plexus to enter the muscle.

The **musculospiral nerve** is commonly injured in fractures of the shaft of the humerus. Its paralysis causes "drop wrist," the peculiar inability to extend the wrist. The injury may be a severe contusion inflicted by displaced fragment, or it may be a compression of the nerve by its involvement in callus. Frequently both conditions exist. Fracture alone rarely causes division of the nerve. Paralysis of the nerve due to contusions, pressure against the operating table, and wounds may also require treatment. In these cases due to temporary pressure recovery may be expected without treatment. In paralysis due to wounds the nerve should be exposed and dealt with. Because of the importance of this nerve the treatment of fractures of the humerus should be conducted in such a manner as to give the minimum of displacement and callus. Outward bowing of the shaft should be guarded against.

In simple fractures with paralysis, the bone should be put in position and as good a bony result as possible secured. The paralyzed muscles should receive electric treatment, and, as soon as bony consolidation will permit, massage. If the paralysis persists after the traumatic reaction has subsided and the bone is solid, operation is called for.

In compound fractures, if the nerve has been injured, if the wound is

large, the nerve may be exposed at once and given any attention which seems indicated (see Wounds of Nerves, page 852). If infection seems inevitable, attention to the nerve should be deferred.

In healed fractures with paralysis of the musculospiral nerve, the paralyzed muscles should receive daily massage. If there are evidences of laceration of the nerve, compression which shows no signs of improvement, or the reaction of degeneration, operation should be done. The nerve should be exposed by a longitudinal incision at the site of injury or approximate to it. To reach the nerve at the middle of the shaft, an incision is made from the posterior border of the deltoid muscle at its insertion downward for 8 cm. (3 inches). Lower down, it is reached by an incision along the front of the triceps on the outer side of the arm, and exposed as it winds forward and downward anterior to the external condyle.

If divided, the nerve should be sutured. If infiltrated with much scar tissue, it should be resected. If constricted in scar tissue or callus, it should be liberated, the compressing tissue removed and the nerve either stretched or resected (see Neurectasy, page 860; Nerve Suture, page 853; and other Operations on Nerves, page 852). The results are most gratifying. Successful operations have been done for paralysis of this nerve over two years after the injury.

The **ulnar nerve** is injured by wounds and by fractures. It is peculiarly exposed as it passes behind the internal condyle of the humerus where it lies under the skin. Its paralysis causes "claw-hand," the peculiar condition in which there is hyperextension of the upper row of phalanges and flexion of the lower two rows, with cutaneous anesthesia. These injuries should receive the general treatment already described. If the nerve has been divided it should be sutured. Following fractures at the elbow the nerve may sustain injuries similar to those of the musculospiral in higher fractures. The treatment should be the same.

Dislocation of the ulnar nerve, whether traumatic or congenital, is apt to recur unless given proper treatment. In these cases, the nerve can be felt as a movable cord, which slips forward over the condyle when the elbow is flexed. The congenital or chronic cases, characterized by recurrences, should be treated by exposure of the nerve and its fixation behind the condyle. This can be done by removing the connective tissue in which it slides, deepening its bed, and suturing a portion of the fascia from the triceps muscle over it to hold it in place. It may be necessary to suture the periosteum over it. If as a result of its traumatisms a localized chronic neuritis has developed, the nerve should be stretched before being fixed.

The **median nerve** is often injured in wounds of the forearm. When paralyzed, there is loss of flexion of the middle phalanges, loss of flexion, abduction and apposition of the thumb, loss of sensation, etc. The treatment of its injuries is the same as that already described for other nerves (page 850).

The **intercostal nerves** are not of sufficient importance to demand suture when divided; but their injuries should be treated so as to minimize the possibilities of neuralgia.

Intercostal neuralgia should be differentiated from pleuritic pains. It lasts usually from a week to two months. Sometimes it is persistent. It should receive the general treatment described for neuralgia (page 862). One of the most effective treatments consists in the application of deep massage pnd vibration to the nerve roots as they emerge from the spine. Vibratory applications may be made also along the course of the nerve. Injections of alcohol are often effective. When all discoverable causes have been removed,

and the disease refuses to yield to other measures, operation is called for. Usually a number of nerves are involved. Their roots should be exposed by an incision parallel with the spine, 5 cm. from the median line. The intercostal spaces are exposed, the external intercostal muscles divided near the lower border of the ribs, and the nerves resected and avulsed or stretched centrally (Fig. 699). Caries and necrosis of vertebræ should be borne in mind as etiologic factors in this disease, and if present given appropriate treatment.

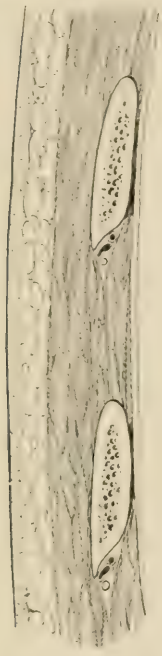


Fig. 699.—Relations of Intercostal Nerve, Vein and Artery Below Border of Ribs.

The **sciatic nerve** is of interest chiefly in connection with neuralgia (page 862). When divided it should be sutured (see Wounds of Nerves, page 850). If cut partly in two, the wound should be sutured. Resection of segments of the nerve sometimes becomes necessary in the removal of tumors of the thigh. Nerve bridging (page 855) then is applied.

The **external popliteal** is often injured because of its exposed position as it winds round the fibula just below its head to gain the front of the leg. Its close relation to the external hamstring tendons subjects it to danger in operations. It may also require attention for paralysis caused by pressure during narcosis, pressure upon the operating table, or from splints and bandages. Peroneal palsy involves the peronei muscles, the dorsal flexors of the ankle and the extensors of the toes, and gives the characteristic "drop foot." The **anterior tibial** nerve is sometimes injured in fractures of the tibia. The treatment of these injuries is like that of other nerves. When one of these nerves becomes paralyzed beyond repair, its function may be restored by grafting it with an unaffected nerve (see Nerve Grafting, page 857).

The **cervical sympathetic ganglia** are three in number, having connecting cords, giving off and receiving numerous branches. The nerve and ganglia are located behind the sheath of the carotid artery to the inner side of the vagus nerve, lying in front of the muscles which are anterior to the cervical vertebræ. They are developed upon the nerve which is usually multiple. The upper ganglion is a fusiform, reddish-gray body, about 2½ to 4 cm. (1 to 1½ inches) in length.

These nerves are connected with the mechanism which controls certain functions of the brain, the eyes, blood-vessels of the head and neck, and the heart. Resection of the ganglia causes contraction of the pupil; ptosis of the upper eyelid; recession of the eyeball; decrease of ocular tension; dilatation of the vessels of the head and neck; increase of tears, nasal secretion and saliva; increase of perspiration of the head and neck; and decrease of the pulse-rate. Most of these symptoms are temporary. The ptosis is permanent. If the pulse has been rapid from sympathetic overstimulation, it is permanently slowed by resection of the ganglia.

Because of influence of the sympathetic upon these functions, its resection has been practised in several different diseases. The operation is done on one or both sides; and removal of the upper one or two ganglia, or of all three, is practised.

In *glaucoma* the upper ganglion only on the affected side is removed. The operation may be regarded as still in an experimental stage. Its results cannot be predicted. Some cases are cured or improved, others are not

helped. The operation is indicated in acute and subacute glaucoma, if iridectomy fails, and in simple glaucoma if miotics fail. Many cases are cured which have resisted all other methods of treatment.

In *exophthalmic goiter* the bilateral removal of all of the cervical sympathetic ganglia has been done to interrupt the vicious connection between thyroid, eye and heart. The operation is not yet upon a positive footing. The mortality and the percentage of cures are less than in thyroidectomy, but the percentage of cases improved is greater. The operation does not obviate the dangers of postoperative acute thyroidism.

In *epilepsy* both upper and both lower ganglia have been removed, with the object of inducing cerebral hyperemia and of cutting off reflex sympathetic impulses to the brain from the abdomen. The sympathetic branches following the carotid and the vertebral artery are thus cut off. The hyperemia thus induced is most probably temporary. The results thus far attained do not justify the acceptance of the operation as a therapeutic procedure.

Resection of the cervical sympathetic ganglia is done as follows: The shoulders and upper thorax are lifted forward and the head is dropped backward and the face rotated toward the opposite side. To expose the three ganglia, an incision is made along the posterior border of the sternomastoid muscle from the base of the skull to the clavicle. The sheath of the muscle should be incised longitudinally and the muscle retracted forward and inward. The spinal accessory nerve entering the muscle in its upper part should not be injured, and the branch to the trapezius should be avoided. The deep fascia, represented in the posterior sheath of the muscle, should be divided in a line with the skin incision. The internal jugular vein, carotid artery, and vagus nerve, all enclosed in their sheath, are retracted inward. The muscles lying in front of the cervical vertebræ form the floor of the wound. The sympathetic nerve enclosed in an aponeurotic envelope lies in front of these muscles directly behind the normal location of the sheath of the carotid artery. If not found, it may have been retracted with the vessels. The nerve may be identified by following it up to the superior ganglion. The ganglion may be isolated by blunt dissection, the branches divided, and the nerve above the ganglion cut or avulsed. The nerve is then followed downward to the inferior thyroid artery, the second ganglion isolated, and the branches divided. The artery may be ligated if the case is one of goiter. To reach the third ganglion, the nerve is followed downward; the scalenus anticus is retracted downward and outward with the vertebral vessels and the thyroid axis; the sternomastoid with the carotid and jugular is retracted inward and forward; the ganglion is dissected off from the vertebral artery and surrounding structures, its branches divided, and the ganglion removed. The important point in the removal of this third ganglion is that the surgeon shall identify the surrounding structures. The vertebral artery should be well in view, the carotid, vagus, internal jugular and pleura should be located and protected.

INDEX OF NAMES

Abrashanoff, 308
Adams, 712, 714
Albee, 507, 510, 511, 512, 513, 514, 516, 517, 739, 774, 775, 776, 777, 778, 779, 784, 785, 786, 787
Alexinsky, 893
Allen, 80, 129, 131, 141, 144, 147, 149
Allis, 106, 107, 634
Andrews, 120, 339
Anel, 383
Annandale, 716, 724
Antyllus, 382
Audree, 769

Baccelli, 268
Ballance and Stewart, 857
Bardenheuer, 498
Bartlett, 36, 615
Bayliss, 348
Beck, 306
Bernheim, 353, 354, 355
Bernheim and Voegtlin, 458
Bevan, 273
Bickham, 395, 404, 406, 407, 408, 416, 421, 433, 438, 443
Bier, 134, 229, 230, 233, 264, 280, 282, 309, 528 664, 686, 699, 817
Biesalski and Mayer, 812
Bigelow, 640, 643, 645
Bigelow and Smith, 641
Billroth, 119, 716
Blach, 458
Blair and McGuigan, 447
Blasius, 623
Boeckel, 718, 719, 723, 724, 746
Bonnet and Meckel, 148
Bookman, 201, 202
Bougard, 331
Brabant, 705
Bradford, 583, 615, 666
Bramson, 250
Brasdor, 383
Brault, 849
Braun, 146, 148, 149
Buck and Gross, 488
Bulkley, 841
Bum, 879
Bunting and Yates, 465
Burkardt, 115
Byrne, 331
Byrnes, 295

Calmette, 275
Campailla, 289
Campbell, 530
Cannon, 217
Carrel, 247, 375
Carrel and Dakin, 242
Carrel and Guthrie, 446
Castellani, 464
Chantemesse, 459
Chaput, 493
Charcot, 681
Chieni, 716
Clark, 892
Codivilla, 486, 495
Coley, 332
Colles, 575
Conrad, 174
Cooper, 631
Corrigan, 370
Cotton, 621
Couteaud, 550
Crile, 176, 177, 213, 214, 215, 216, 217, 348, 349, 352
Cunningham, 122
Cushing, 890

Dakin, 60, 63, 73, 242, 247
Dakin and Carrel, 242
Daufresne, 61
Davison, 512, 517
de Forest, 623
Delbet, 117, 390
Denker, 724
Desault, 383
Deschamps, 383
Dieffenbach, 718, 722
Doane, 789
Doberauer, 455
Dodd, 220
Dorrance, 374
Doyen, 691
Dreuw, 834
Duncan, 169
Dunham, 63
Dupuytren, 606

Eastman, 200
Eck, 458
Ehrlich, 284, 291, 294, 302
Eisenstaedt, Lespinasse and Fisher, 377
Ellis and Swift, 295
Elsberg, 536, 705
Erhardt, 161
Esmarch, 56, 107, 229, 367, 679, 726, 751, 854

Farabeuf, 735
Fehleisen, 332
Fergusson, 718
Finsen, 280, 837
Fischer, Eisenstaedt and Lespinasse, 377
Fox, 253

Fraenkel, 664
Freeman, 507
Fulda, 706

Gant, 714
Gatch, 121, 122, 123
Gauss, 366
Gelyi, 365
Gergö, 234
Gettler and Lindeman, 177
Gifford, 476, 593, 594
Goldmann, 709
Goldthwait, 582
Gottheil, 288
Gray, 405
Gross and Buck, 488
Guerche, 269
Guérin, 719, 722
Guillard, 99
Guthrie and Carrel, 446
Gwathmey, 100, 102, 110, 122

Hackenbruch, 497
Hallion and Tuffier, 390
Halsted, 384, 392
Hammond and Sharpe, 296
Handley, 462, 463
Hare, 382
Harrington, 59
Harrison, 47
Hartwell, 352
Hassler and Honan, 115
Heald, 196, 198
Hecht, 879
Heiser, 836
Helferich, 760, 762
Helmholz, 355
Henderson, 108, 213, 779
Hess, 342
Hewitt, 99, 122
Hibbs, 615, 780, 781, 782
Hodenpyl, 333
Hodgen, 585
Hodgkin, 464
Hoffa, 613, 684, 685, 783, 805
Hogan, 347
Holzknecht, 223
Honan and Hassler, 115
Hooker, 260
Horsley, 378
Hunter, 383

Jackson, 847
Jianu, 446
Joani, 374
Jonnesco, 161
Jett, 191
Junker, 124

Kanavel, 345, 861
Kaposi, 847
Katzenstein, 769
Keen, 379, 392, 397
Kennedy, 890
Kingsley, 544, 546
Koch, 257, 258
Kocher, 267, 627, 628, 631, 644, 645, 730, 742, 744, 751, 872, 875
Korotkow and Pachon, 390
Kraus, 272
Krause, 323
Kromayer, 289
Kroner and Oelsner, 161
Krönig, 332
Krönlein, 876
Kümmell, 115, 396

Labarraque, 164
Lambotte, 462
Lambotte and Putti, 506
Landon, 349, 352
Lane, 508
Lange, 801
Langenbeck, 711, 719, 721, 722, 723, 724 741, 748
Lanz, 463, 464
Lassar and Spronk, 332
Lauenstein, 755
Le Conte, 247
Lemon and Mueller, 485
Lennander, 146
Lespinasse, Fischer and Eisenstaedt, 377
Lewisohn, 356
Lexer, 768
Libman and Ottenberg, 355
Lilienthal, 740
Lindeman, 353
Lindeman and Gettler, 177
Lister, 746
Liston, 721
Locke, 58, 177
Lockwood, 172
Lorenz, 613, 617
Lovett, 670, 671, 802
Lowman, 498
Lumbard, 110

Macewen, 382, 712, 714, 715, 716
MacDonald, 796
Malgaigne, 573, 602, 722
Marcy, 37
Marsden, 331
Martin, 229, 311, 506
Mason, Sydenstricker and Rivers, 355
Matas, 270, 384, 389, 390, 391, 393, 395, 545, 547
Matti, 456
Mayer, 716
Mayer and Biesalski, 812
Mayo, 451, 452
McBurney, 631, 646
McCrae and Osler, 257
McDonald, 70, 178
McGuigan and Blair, 447
Meckel and Bonnet, 148
Medalia, 832
Mellish, 467
Meltzer, 267, 268
Meltzer and Peck, 164
Mencière, 70, 271
Meyer, 232, 233, 457
Meyer and Weidig, 119
Michel, 187

Mikulicz, 664, 736, 737
Milliken, 263
Mitchell, 153, 308
Momburg, 363, 365
Morestin, 271
Moriarty, 546
Morison, 248
Mosetig-Moorhof, 705
Moskowicz, 390, 391
Mueller, 699, 702
Mueller and Lemon, 485
Müller, 234
Murphy, 281, 455, 664, 762, 764

Nathan, 661
Neff, 384
Nélaton, 623, 718
Nichols, 695
Noel and Souttar, 164
Noguchi, 284
Nydegger, 555

Oelsner and Kroner, 161
Ogilvie, 295
Ogston, 714, 715
Ollier, 718, 721, 722, 724, 741, 746, 748, 755
Ormsby, 99
Osler and McCrae, 257
Ottenberg and Libman, 355
Oulmann and Wollheim, 297

Pachon and Korotkow, 390
Paré, 339
Parham, 506
Parkhill, 507
Pasquin, 383
Passavant, 823
Pasteur, 255, 273
Patrick, 870
Payr, 378, 838
Peck and Meltzer, 164
Penhallow, 561
Philagrius, 383
Phillips, 583
Phisalix, 275
Pilcher, 578
Porter, 266
Post, 119
Pott, 606
Priestley, 120
Prout, 892
Purmann, 383
Putti and Lambotte, 506

Quénu, 762
Quillian, 177

Ramström, 148
Ransohoff, 134
Ream, 100
Reder, 192
Reeves, 716
Rivallié, 74
Rivers, Sydenstricker and Mason, 355
Rogers, 266
Rollier, 280
Rose, 269
Rosengarten, 62
Rothschild, 795
Russ, 57
Ruth, 583
Rydygier, 647

Sauerbruch, 267, 353
Sayre, 552, 555, 748
Schäfer, 98
Schanz, 225, 602
Schede, 452, 704, 716
Schiassi, 58, 239
Schichhold, 628
Schleich, 119, 135, 497
Sclavo, 272
Senn, 507, 741
Shaffer, 652
Sharpe and Hammond, 296
Shaw and Williams, 203
Sherman, 705
Sinclair, 55
Skillern, 311
Smith, 610
Smith and Bigelow, 641
Soresi, 350, 352
Souttar and Noel, 164
Spitzy, 529, 531
Spronk and Lassar, 332
Stebbing, 357
Steinmann, 495
Stelwagon, 847
Stewart and Ballance, 857
Stillians, 844
Stimson, 475, 545, 607, 619, 623, 629, 643 644
Stoffel, 852
Strickler, 840
Swift and Ellis, 295
Sydenstricker, Mason and Rivers, 355
Sylvester, 98

Taylor, 592, 675, 892, 895
Teter, 100, 122
Thiersch, 74
Thomas. 585, 589, 668, 669, 673, 675, 678 748, 749
Torres, 266
Trendelenburg, 449, 452, 457
Trombetta, 880
Tuffier and Hallion, 390
Tunnicliffe, 357
Tzaiçon, 224

Unger, 354
Unna, 310, 311

Van Cott, 256
Vance, 467
Variot, 849
Velpeau, 718, 721, 722
Vincent, 354
Voegtlin and Bernheim, 458
Volkmann, 491, 604, 605, 714
von Frisch, 390
von Langenbeck, 711, 719, 721, 722, 723, 724, 741, 748
von Mosetig-Moorhof, 705

Warbasse, 469, 523, 526, 527, 537, 566, 599, 605, 695
Wardrop, 383
Warfield, 296
Wassermann, 283, 284, 294, 297, 299
Watson, 347
Weber, 718
Weidig and Meyer, 119
Weil, 459
White, 748, 796
Whitman, 587
Wicks, 204
Wieting, 377, 455
Williams and Shaw, 203
Woelfler, 73
Wolf, 617
Wollheim and Oulmann, 297
Woolsey, 122
Wright, 58, 241, 258, 355
Yates and Bunting, 465
Zechmeister, 269
Ziehl, 829
Zuppinger, 494

INDEX OF SUBJECTS

Abdomen, operations on, prevention of shock in, 215
Abdominal aorta, aneurism of, 397
compression of, in hemorrhage, 360
ligation of, 426
binders, 50
section, local anesthesia in, 149
sheets, 48
sponges, 44
wall, operations on, local anesthesia in, 148
Abscesses, 251
antiferment treatment, 234
Bier's hyperemia for, 231
chronic, 253
excision of, 254
drainage in, 252
dressings for, 252
ether for, 235
hot fomentations in, 251
in tuberculosis of hip, 672
incision in, 251
isolated chronic, filling bone cavities in, 706
local antiseptic treatment, 234
septicemia from, vaccines in, 257
tuberculous, 281. See also *Tuberculous abscess*.
Absorbable ligatures, 33
sutures, 33
Absorbent cotton, 41
Acacia, gum, in saline infusion, 348
Acapnia, 213
in anesthesia, 123
Acarus scabiei, 848
Accessories, surgical, 48
Accessorius-facial nerve grafting in facial paralysis, 885
Accidental wounds, 166
treatment, 186
A. C. E. anesthetic mixture, 119
Acetabulum, dislocations of hip through floor of, 645
Acetal anesthesia, 118
Acetic acid as antiseptic, 67
Acetone-pyxol solution for hand sterilization, 174
for preparation of operative field, 178
Acetotartrate of aluminium as antiseptic, 68
Achondroplasia, 471
Acid, acetic, as antiseptic, 67
benzoic, as antiseptic, 67
bichlorid solution as antiseptic, 59
boric, as antiseptic, 67
citric, as antiseptic, 72
hydrochloric, as antiseptic, 72
Acid mercuric nitrate as caustic, 74
oxalic, as antiseptic, 67
picric, as antiseptic, 67
in burns, 821
salicylic, as antiseptic, 67
sulphuric, as antiseptic, 72
Acidosis in surgical shock, 213
prevention of, 176
treatment of, by alkalinized transfusion 177
Acne, 835
rosacea, 836
Acriflavin as antiseptic, 65
Acromegaly, 321
Acromion process, fractures of, 556
Actinomycosis, 272
of muscle, 792
Actol as antiseptic, 67
Acupressure in hemorrhage, 341
Adamantine epithelioma, 709
Adenoma, 325
Adherent scars, 225
Adhesions, prevention of, 816
Adhesive paste, 55
plaster protective, 54
straps for wounds, 187, 188
support for tension sutures, 198
tapes, 35
Adrenalin chlorid as hemostatic, 341
for treatment of shock, 217
gauze, 41
in local anesthesia, 139
Age as factor in surgical treatment, 19
Agglutination, testing for, in blood transfusion, 355
Ainhum, 320, 843
Air cushions, 23
embolism, 447
fresh, in surgical treatment, 21
in hemorrhage, 344
injections in sciatica, 879
Akoin as local anesthetic, 137
Albee's bone grafts in fractures, 507
methods of holding bone grafts in place, 510
Albuminuria in varicose ulcers, 312
Alcohol as antiseptic, 72
injections for nerve blocking, 864
in incurable carcinoma of tongue, 869
in neuralgia, 864
in spastic muscles, 795
in trifacial neuralgia, 866
in Gasserian ganglion, 869
method for catgut, 35
solidified as antiseptic, 72
Alcoholic soap as antiseptic, 72

Alcoholism as factor in surgical treatment, 18
in operation, 180
Aleppo boil, 273
Allis' ether inhaler, 106
operation for habitual shoulder dislocations, 634
Alopecia, 846
areata, 847
follicularis, 847
syphilitic, 303
Aluminium acetotartrate as antiseptic, 68
bronze sutures, 38
Alumnol as antiseptic, 72
Alveolar process of jaw, fractures of, 543
of lower jaw, resection of, 725
of upper jaw, resection of, 723
Alypin as local anesthetic, 136
Ambulant treatment of fractures, 522
Ambulatory splints, 522
Ammonium sulphate method for catgut, 35
Amputation in compound fracture, conditions calling for, 520
Amylene anesthesia, 118
Analgesia, 92
Anaphylaxis to antitetanic serum, 266
Anastomosis, arterial, Horsley's clamp for, 379
arteriovenous, 377
end-to-end, of arteries, 374
Ancestral peculiarities as factor in surgical treatment, 18
Anemia, artificial local, in hemorrhage, 367
as factor in operation, 182
from hemorrhage, 343
local anesthesia by, 155
pernicious, hemorrhage in, 360
Anesthesia, 92
acapnia in, 123
acetal, 118
amylene, 118
antidolorin, 117
artificial respiration in, 98
auto-, 102
bromethyl, 118
bromoform, 118
by laryngeal puncture, 125
by larynx, 125
by local anemia, 155
by nerve pressure, 155
by pharynx, 124
by suggestion, 127
chloroform, 116. See also *Chloroform anesthesia.*
chloroform-ether sequence, 119
chloroform-oxygen, 120
complete surgical, 97
dimethylacetal, 118
epidural sacral injections for, 162
ether, 104. See also *Ether anesthesia.*
ether-oxygen, 120
ethyl bromid, 118
chlorid, 117
chlorid-ether sequence, 119
for reducing dislocations, 610
from cold, 154
Anesthesia, gas-ether sequence, 118
general, 92
after-effects, treatment, 104
amount of anesthetic required, 100
artificial respiration in, 98
care of patient, 101
clearing of throat in, 97
color of patient in, 99
contraindications to, 102
duties of anesthetist in, 95
examination before, 92
eye in, 99
holding tongue in, 97
in children, 102
in status lymphaticus, 102
intravenous, 164
massage of heart in, 99
mental state before, 94
morphin before, 92
mortality in, 99
mouth gags for, 95
points to watch in, 97
position for, 94
primary stage, 97
protection of lips in, 100
pulse in, 98
purge before, 94
respiration in, 97
restraint in, 101
selection of anesthetic in, 101
state of excitement, avoidance, 96
stimulants in, dangers of, 98
stimulation in, 98
technic, 95
tests for, 97
time required for, 97
tongue forceps for, 95
traumatic paralysis in, 100
hydrobromic ether, 118
hypercapnia in, 123
hypnotic, 126
infiltration, 127
intermittent, 101
intratracheal, 125
kelen, 117
laughing gas, 117
local, 127. See also *Local anesthesia.*
methylal, 118
methylene bichlorid, 118
ether, 118
mixed, 118
mixtures, 119
nitrous oxid, 117
oxid-carbon dioxid, 123
oxid-oxygen, 120
oil-ether rectal, 110. See also *Oil-ether rectal anesthesia.*
operations without, 165
parasacral, 162
paravertebral, 152
pental, 118
rebreathing with, 122
regional, 127
sequences, 118
somnoform, 118
spinal, 155. See also *Spinal anesthesia.*
sterile water, 139

Anesthesia, surface contact, 127
terminal, 128
Anesthesin in local anesthesia, 137
in tuberculous laryngitis, 137
Anesthetics, 92
choice of, 103
combined with oxygen, 120
injection of nerve roots with, 152. See also *Nerves, blocking of.*
local, 134
poisoning from, 138
mixtures of, 119
operations without, 164
selection of, in general anesthesia, 101
warm versus cold, 103
with carbon dioxid, 122
Anesthetist, duties of, in general anesthesia, 95
Anesthetizing cart, 94
room, 167
Anesthol, 119
Aneurism, 380
arteriovenous, 393
axillary, 399
carotid, 399
chronic, 381
cirsoid, 400
compression of artery in, 381, 382
dissecting, 380
electricity in, 381
electrolysis in, 382
femoral, 398
gradual obliteration of arteries in, 384
hygienic treatment, 381
irritation of sac in, 382
ligation of artery in, 382
medical treatment, 381
Neff's clamp, 384
obliterative operation, 385
of abdominal aorta, 397
of buttock, 398
of external iliac artery, 398
of innominate artery, 399
of internal iliac artery, 398
of thoracic aorta, 396
pelvic, 398
plication of arteries in, 384
popliteal, 399
reconstructive operation in, 389
restorative operation in, 389
spontaneous cure, 393
subclavian, 400
traumatic, 380
wiring in, 382
Aneurismectomy, 391
with arteriorrhaphy, 392
with transplantation of vein and artery, 392
Aneurismorrhaphy, 384
Angeitis, obliterating, gangrene from, 316
Angioma, 325, 453
cavernous, 454
electrolysis in, 453
spongy, 454
Angiosarcoma of bones, 710
Angiotribe, 80
in hemorrhage, 339, 340
Anidrosis, 844
cold cream for, 849
Animal fat, influence of, on leukocytosis, 20
membranes, 74
parasites of skin, 848
Ankle, dislocations of, 649
congenital, 618
excision of, 753. See also *Excision of ankle.*
sprains of, 650
tuberculosis of, 678
Ankylosing arthritis, plastic, 662
Ankylosis after fractures of lower extremity of humerus, 571
cartilage grafts in joint resections for, 759
excision of elbow for, 745
interposition of foreign membranes in, 759
of periosteum for, 759
of soft tissue flaps in, 757
of elbow, arthroplasty for, 762
of hip, arthroplasty for, 765
osteotomy in, 713
of joints, 686
operative treatment, 686
of knee, arthroplasty for, 766
with deformity, bone grafts in, 787
of lower jaw, Esmarch's operation for, 726
excision of condyle for, 726
operations for, 726
of patella, arthroplasty for, 767
of shoulder, arthroplasty for, 761
of spine, bone grafts to produce, 780
of temporomaxillary joint, arthroplasty for, 760
of wrist, arthroplasty for, 764
operations for, 757
prevention of, by oil injections, 756
transplanted soft tissues for, 758
Annandale's operation through upper jaw to reach nasopharynx, 724
Anoci-association, 213, 214
Anoxemia, 123
Anthrax, 271
operative treatment, 271
serum treatment, 272
vaccine treatment, 272
Antibody antagonism as factor in surgical treatment, 26
Antidiphtheritic serum in hemorrhage, 342
Antidolorin anesthesia, 117
Antiferment treatment of abscesses, 234
Antisepsis, 27
Antiseptics, 57, 59
intravenous injection, in septicemia of unknown origin, 261
treatment of infected wounds with, 242
Antistreptococcic serum as hemostatic, 342
Antitetanic serum, 265
anaphylaxis to, 266
dried, 265
in frost-bite, 265
intravenous injection, 266
method of injection, 266
saturation dose, 266
spinal injection, 266
Antitoxins, 255

Antitoxins in anthrax, 271
in septicemia, 260
Antivenene in snake bite, 275
Anuria, postoperative, 226
Anus, eczema of, 832
operations on, local anesthesia in, 152
preparation of, for operation, 180
pruritus of, 843
Aorta, abdominal, aneurism of, 397
compression of, in hemorrhage, 360
ligation of, 426
thoracic, aneurism of, 396
Apothesin as local anesthetic, 137
Appendectomy, local anesthesia for, 150
Appendicitis simulated by contracture of psoas parvus muscle, 796
Applications, 57
Approximation sutures, 196
Areas, sensory pain, 128
Argenol as antiseptic, 67
Argentamin as antiseptic, 67
Argentized catgut, 36
Argentos as antiseptic, 67
Argonin as antiseptic, 67
Argyrol as antiseptic, 67
Aristol as antiseptic, 70
Arm, brawny, 463
muscles moving, 893
paralysis of biceps, tendon transplantation in, 812
Arsenic in inoperable cancer, 332
paste as caustic, 74
Arsenobenzol in syphilis, 298
Arsphenamin in syphilis, 298
Arterial infusion, local anesthesia by, 134
occlusive gangrene, 317
tension, high, as factor in operation, 180
Arteries, 371
anterior tibial, ligation of, 443
axillary, ligation of, 415
indications for, 418
brachial, ligation of, 418
catheterization of, 380
common carotid, anatomy, 406
ligation of, 406
at inferior carotid triangle, 407
at superior carotid triangle, 408
indications for, 408
slow, 408
iliac, ligation of, 426
extraperitoneal, 426
compression of, in aneurism, 381, 382
in hemorrhage, 360
dorsalis pedis, ligation of, 445
end-to-end anastomosis of, 374
external, carotid, ligation of, 409
iliac, ligation of, 429
facial, ligation of, 412
femoral, anatomy, 434
embolism of, 455
ligation of, 431
for varicose veins, 453
indications, 436
gluteal, ligation of, 430
gradual obliteration of, in aneurism, 384
iliac, common, embolism of, 455
inferior thyroid, ligation of, 410
Arteries, inflammations of, 380
innominate, ligation of, 403
indications for, 406
internal carotid, ligation of, 410
iliac, ligation of, 430
pudic, ligation of, 431
lateral anastomosis of, Horsley's clamp for, 379
ligation of, in aneurism, 382
materials for, 402
technic, 401
lingual, ligation of, 411
loss of substance in, 379
occipital, ligation of, 412
occlusion of, 401
of head and neck, ligation of, incisions for, 404
plication of, in aneurism, 384
popliteal, ligation of, 437
posterior auricular, ligation of, 412
tibial, ligation of, 441
in middle of leg, 442
press for compression in hemorrhage, 366
pulmonary, embolism of, 457
radial, deep palmar branch, ligation of, 426
ligation of, 421
sciatic, ligation of, 431
subclavian, ligation of, 413
superior thyroid, ligation of, 411
suturing of, 371. See also *Suture of arteries.*
temporal, ligation of, 412
traumatism of, 371
ulnar, ligation of, 424
vertebral, ligation of, 410
wounds of, 371
ligation in, 338
Arteriorrhaphy, aneurismectomy with, 392
Arteriovenous anastomosis, 377
aneurism, 393
Arteritis, 380
chronic, 380
Arthrectomy, 710
in knee-joint, 710, 752
in tuberculosis of joints, 665
of knee-joint, 677
Arthritis, 657
chronic, 661
deformans, 661
gonorrheal, 660
in influenza, 660
infective, acute, 658
plastic ankylosing, 662
pneumococcus, 660
rheumatic, 660
rheumatoid, 661
specific acute, 660
typhoid, 660
Arthrodesis, 738
in flatfoot, 739
in hammer-toe, 739
in infantile paralysis, 738
in osteo-arthritis, 739
in paralytic relaxation of hip, 739
in stiffening of knee-joint, 739
in wrist-drop, 739

Arthropathy, tabetic, 681
Arthroplasty, 757
for ankylosis of elbow, 762
of hip-joint, 765
of knee-joint, 766
of patella, 767
of shoulder-joint, 761
of temporomaxillary joint, 760
of wrist-joint, 764
Arthrotomy, 755
in old unreduced dislocations of hip, 646
incisions for, 756
of knee-joint, 756
Articular rheumatism, acute, 660
Artificial hyperemia, 229–232. See also *Bier's hyperemia.*
respiration in general anesthesia, 98
Asbestos absorbent wool dressings, 42
Asepsis, 27, 166. See also *Sterilization.*
Aseptic surgical fevers, 259
wounds of joints, 654
Asphyxia, traumatic, hemorrhage in, 360
Aspirating jar, 81
syringe, 81
Aspiration, aseptic, of tuberculous abscess, 281
pneumonia from ether, 105
Aspirator, 79
Assistants at operation, personal care, 172
Astragalus, dislocations of, 649
excision of, 735, 736
fractures of, 608
Astringents in hemorrhage, 341
Atlas and axis, dislocations between, 622
Atrophia pilorum propria, 847
Atrophic skin diseases, 843
synovitis, 658
Atrophy, muscular, in fractures, 525
of hair, 847
of nails, 848
Auditory nerve, diseases and injuries of, 890
Auricular artery, posterior, ligation of, 412
Auriculotemporal nerve, division of, in neuralgia, 874
Auto-anesthetization, 102
Autogenous bone grafts, 772
for skull defects, 775
vaccines, 256
results from, 256
Autoplastic bone flaps, filling defects in bones with, 699
flaps, strengthening of sutures by, 203
grafts, 772
nerve bridging, 855
transplantation, 856
Autoserum treatment of skin diseases, 849
Autotoxic neuritis, 862
Avulsion of members, 224
of tubercle of tibia, 603
slow, in neuralgia, 871
Axillary aneurism, 399
artery, anatomy, 417
ligation of, 415
indications for, 418
embolism, 455
Bacillus aërogenes capsulatus, infection with, 270
diphtheriæ, wound infection with, 262
emulsion in tuberculosis, 258
sensitized, in tuberculosis, 258
hodgkini, 465
pyocyaneus infection, 261
Bacterins, 255. See also *Vaccines.*
Bacteriolysis as factor, 26
Bags, sand-, 82
Baldness, 846
Ballance's operation in facial paralysis, 887
Balsam-of-Peru as antiseptic, 71
gauze, 40
Bandages, Esmarch, 56
for inflammation, 229
flannel, 55
gauze, 55
Martin's, for inflammation, 229
muslin, 55
plaster-of-Paris, 57
rubber, 56
starch, 56
T-, 49
triangular, 49
tricot, 55
tripolith, 56
water-glass, 56
Bands, metallic, in fractures, 506
Bartlett's method for sterilizing catgut, 36
Base and vault of skull, fractures of, 537
of skull, fractures of, 534
Bath, daily, 24
warm, in tetanus, 269
Beck's bismuth paste injections in sinuses, 306
Bed cradle, 23, 24
frame for supporting suspension splints, 488
hospital, 22, 23
Bed-lift, 25
Bed-pan, 24
Bed-sores, 313
prevention, 24
skin powder for, 313
Bedbugs, bites of, 275
Beef serum, 59
Bees, stings of, 276
Bell's palsy, 881. See also *Facial paralysis.*
Belt constriction in hemorrhage, 363
Benign cysts, 325
Benzoic acid as antiseptic, 67
Benzoin varnish antiseptic, 73
Benzol in leukemia, 466
Bernheim's clamp for indirect blood transfusion, 353
Beta-naphthol as antiseptic, 71
Biceps femoris, tendon of, tenotomy of, 815
of arm, paralysis of, tendon transplantation in, 812
Bichlorid eczema, 833
gauze, 40
of mercury, 59
method for catgut, 35
Bier's hyperemia, 229–232
active, 229
for inflammation, 229

Bier's hyperemia in malposition of joints, 686
in neuralgia, 863
in tuberculosis, 280
of joints, 664
of knee-joint, 675
in tuberculous abscess, 282
in wound infection, 28
passive, 229
Bigelow's method of reducing hip dislocations, 641, 643
Billroth's anesthetic mixture, 119
Binders, abdominal, 50
breast, 49
Bipp paste in infected wounds, 248
Birth palsy, brachial, 894
Biskra button, 273
Bismuth formic-iodid as antiseptic, 72
gauze, 40
oxyiodid as antiseptic, 71
paste injections in sinuses, 306
treatment of infected wounds, 248
phosphate as antiseptic, 72
salicylate as antiseptic, 72
subcarbonate as antiseptic, 72
subgallate as antiseptic, 71
subiodide as antiseptic, 71
subnitrate as antiseptic, 72
Bites of insects, 275
snake, 274
Blackheads, 845
treatment, 849
Bladder, preparation of, for operation, 180
Blankets, 48
Blastomycosis, 838
Bleaching powder, 61
Bleeding. See *Hemorrhage.*
ulcers, 314
Blocking, nerve, alcohol injections for, 864
Blood as hemostatic, 342
clot, filling bone cavities with, 704
defibrinated, in hemorrhage, 343
sequestration of, for control of hemorrhage, 369
transfusion, 348. See also *Transfusion, blood.*
Blood-pressure, effects of ether on, 105
Blood-serum as hemostatic, 342
Blood-vessels, 334
closing of, absorbable metal clips for, 339
injuries to, in dislocations, 611
laceration of, in fractures, 524
Boeckel's operation through upper jaw to reach nasopharynx, 723
Boiling water, sterilization by, 31
Boils, 253, 827
Aleppo, 273
nasal, 273
Oriental, 273
vaccines in, 253, 829
Bolster sutures, 197
Bone cylinders in fractures, 507
ferrules in fractures, 507
flaps, autoplastic, filling defects in bones with, 699
heteroplastic, 700
grafts, 772
Bone grafts, Albee's, in fractures, 507
autogenous, 772
for skull defects, 775
autoplastic, 772
curved, method of preparing, 780
electric motor for cutting, 691
for filling bone-defects, 772
from cadaver, 772
heteroplastic, 772
in ankylosis of knee-joint with deformity, 707
in bow-leg deformity, 787
in dislocations of hip-joint, 783
in fracture of clavicle, 511
of condyles, 515
of forearm, 512
of humerus, 511
of lower jaw, 518
of malleolus, 516
of neck of femur, 512
of olcranon, 511
of os calcis, 517
of patella, 516
in habitual dislocation of patella, 787
in paralytic scoliosis, 782
in sacro-iliac joint, 783
in spina bifida, 783
in spondylolisthesis, 783
in tuberculous spondylitis, 776. See also *Bone-grafts of spine.*
inlay, method of holding, 774
methods of cutting, 773, 774
of fixation, 772
of astragalus for restoring head of femur, 785
of phalanges, 786
of spine, 776
after-treatment, 781
choice of operation, 781
contraindications, 781
indications for use of, 780
inlaid, in split spinous processes, 777
lateral, 776
results of, 782
to produce ankylosis, 780
of skull, 775
preparation of, 772
sliding, 509
technic, 772
tibial, 772, 773
transplanted, 511
instruments, extemporized, 89
transplantation, 772
Bones, angiosarcoma of, 710
apparatus for moving, in fractures, 497
autoplastic operations with, in osteomyelitis, 698
caries of, 468
chips of, for filling bone cavities, 704
congenital defects of, 471
contusions of, 467
cysts of, 709
denuded, 467
diseases of, 467
displaced, in fractures, 524
enchondroma of, 709
excisions of, 717

Bones, filling cavities in, 701
absorbable materials for, 705
bone chips for, 704, 705
from bone tumors, 706
from tuberculosis, 706
in compound fractures, 706
in epiphyseal caries and necrosis, 706
in isolated chronic abscess, 706
non-absorbable materials for, 705
salt solution for, 705
transference of bone for, 704
with blood clots, 704
with fat, 704
with heteroplastic bone flaps, 700
with organic tissues, 704
with spermaceti wax, 705
defects in, with autoplastic bone flaps, 699
long, giant-cell sarcoma of, 707, 709
osteotomy of, 711
technic, 712
resection of, osteotomy combined with, 716
loss of substance, operations for, 692
medullary fibroma of, 709
metatarsal, excision of, 737
myxochondrosarcoma of, 709
myxoma of, 709
necrosis of, 468
in fractures, 525
of pelvis, resection of, 732
operations on, 688
for lengthening, 770
for loss of substance, 699
instruments for, 688–690
perithelioma of, 710
resections of, 717
sarcoma of, mixed-cell, 709
small round-cell, 709
spindle-cell, 709
suturing of, in fractures, 503
tendon to, 804
syphilis of, 470
tarsal, excision of, 734
transference of, for filling bone cavities, 704
tuberculosis of, 469
tuberculous foci in, uncomplicated, 470
tumors of, 470, 706
amputation in, indications for, 709
conservative operations for, 706
excision in, 708
filling bone cavities from, 706
resection, 706
wiring of, in fractures, 503
Borax as antiseptic, 67
Boric acid as antiseptic, 67
gauze, 41
Boro-salicylic gauze, 41
solution as antiseptic, 68
Bougard's paste in cancer, 331
Bow-leg deformity, bone grafts in, 787
Brachial artery, compression of, in hemorrhage, 360
ligation of, 418
birth palsy, 894
Brachial neuralgia, 896
plexus, blocking of, 154
injection of, in local anesthesia, 145
injuries and diseases of, 892
method of exposure, 893
narcosis paralysis of, 895
Bradford frame in tuberculosis of hip, 666
Braut's method of removing tattoo marks, 849
Brawny arm, 463
Breast binders, 49
operations on, local anesthesia in, 148
Bridging of nerves, 855
autoplastic, 855
heteroplastic, 855
Brilliant green as antiseptic, 65
Bromethyl anesthesia, 118
Bromidrosis, 844
Bromoform anesthesia, 118
Bronchi, operations on, local anesthesia for 144
Bronze wire sutures, 38
Brushes for skin cleansing, 82
Buck's extension in fractures, 488
Bullet wounds, 222
from explosive bullet, 222
of joints, 656
Buried suture, 191
Burns, dichloramin for, 65
from caustics, 825
of skin, 820
extensive, 822
from acids, 825
from caustics, 825
from dry heat, 825
from hot fluids, 825
granulating, 824
hydrotherapy in, 822
of small area, 821
of variable areas, 821
paraffin occlusion treatment, 823
prevention of deformity in, 824
vaccines in, 824
Bursæ, 819
contusions of, 819
wounds of, 819
Bursitis, exostosis, 709
infective, 819
non-infective acute, 819
chronic, 819
tuberculous, 819
Buttock, aneurism of, 398
Button, Biskra, 273
sutures, 197

Calcaneum, excision of, 734, 736
resection of, 734
Calcium hyposulphite as disinfectant, 61
in hemorrhage, 343
Callositas, 841
Callosities of matrix of nails, 848
Callus, 841
bone, 472
excessive, in fractures, 525
Calmette's serum in snake bite, 275
Calomel as antiseptic, 59
in syphilis, 288

Camphor for treatment of shock, 217
Cancer, 327
  Bougard's paste in, 331
  caustics in, 330
  charlatanism in treatment, 330
  early treatment, 328
  etiology, 327
  houses, 327
  inoperable, 331
    drug treatment, 332
    palliative treatment, 331
  Marsden's paste in, 331
  metastases in lymph-nodes, 466
    time of formation, 328
  of bones, 470
  of skin, 843
  of tongue, incurable, alcohol injections in, 869
  prevention, 327
  radical treatment, 328, 329
  spontaneous cure, 331
Canula and trocar, 79
Capillary nevi, 453
Carbolic acid, 65
Carbon dioxid in anesthesia, 122
    treatment in nevus pigmentosus, 842
Carbuncle, 253
  actual cautery in, 253
  circular incision in, 253
  dressings for, 253
  of upper lip, 253
  time for incision, 253
Carcinoma. See *Cancer*.
Cardiac disease as factor in operation, 182
Cargile membrane, 74
Caries of bones, 468
Carotid aneurism, 399
  artery, common, anatomy, 406
      ligation of, 406
        at inferior carotid triangle, 407
        at superior carotid triangle, 408
        indications for, 408
        slow, 408
    compression of, in hemorrhage, 360
    external, ligation of, 409
    internal, ligation of, 410
  triangle, inferior ligation of common carotid at, 407
    superior, 406
      ligation of common carotid artery at, 408
  tubercle, 407
Carpometacarpal joints, dislocations of, 639
Carpus, dislocation of, 638
    individual bones, 639
  fractures of, 579
Carrel-Dakin instillation method for infected wounds, 242
Cart, anesthetizing, 94
Cartilage grafts in joint resections for ankylosis, 759
Cartilages, costal, dislocations of, 623
  fractured, 653
  of joints, dislocation of, 652
  semilunar, of knee-joint, dislocation of, 652
Cataplasma kaolini for inflammations, 234
Catgut, 33
  argentized, 36
  braided, 34
  chromic, for ligating arteries, 402
  chromicized, 36
  for ligatures, 337
  sizes, 33
  sterilization of, 34
    alcohol method, 35
    ammonium sulphate method, 35
    Bartlett's method, 36
    bichlorid of mercury method, 35
    camol method, 34
    dry heat method, 36
    formalin-iodin method, 36
    formalin method, 36
    iodin method, 35
    moist heat method, 36
    paraffin method, 36
    potassium mercuric iodid for, 35
    tannic acid method, 37
    toluol method, 35
  sterilized, in tubes, 34
Catheterization of arteries, 380
Caustics, 73
  in cancer, 330
  in inoperable cancer, 331
Cauterization in inoperable cancer, 331
Cautery, actual, 80
    in carbuncle, 253
  as hemostatic, 339
  cutting, 80
  electric, 80, 83
  Paquelin, 80
Cavernous angioma, 454
C. E. anesthetic mixtures, 119
Cellulitis, 264
  diffuse acute, 250
  elastic bandage in, 229
  gangrenous, 318
Celluloided linen sutures, 38
Cement dressings, 56
Centipedes, bites of, 276
Cerebrospinal fluid in spinal anesthesia, 156
Cervical lymphatics, operations on, local anesthesia for, 145
  nerves, injuries and diseases of, 890
  sympathetic ganglia, injuries to, 898
      removal of, in epilepsy, 899
        in exophthalmic goiter, 899
      resection of, 899
      upper, removal of, in glaucoma, 898
  vertebræ, lower six, dislocations of, 622
Cervico-occipital neuralgia, 890
Chain suture, 195
    tied, 200
Chalk paste in fistulas, 308
Chancre, syphilitic, excision of, 284
    treatment, 302
Chapped hands, 849
  lips, 832
Charcoal dressings, 42
Charcot's disease of joints, 681
Charlatanism in cancer treatment, 330
Chart, narcosis, 96
Chemicals, sterilization by, 30
Chigo, bites of, 276

Chilblains, 319, 826
Children, general anesthesia in, 102
susceptibility of, to shock, 19
Chinosol as antiseptic, 60
Chloasma, 840
Chloral hydrate as antiseptic, 73
in tetanus, 267
Chloraminated oil as antiseptic, 64
in compound fractures, 519
in infected wounds, 247
treatment for infected wounds, 247
Chloramin as antiseptic, 60
for treatment of infected wounds, 242
Chlorazene as antiseptic, 60, 64
gauze, 41
in infected wounds, 247
Chlorcosane as antiseptic, 65
Chloretone gauze, 41
in tetanus, 267
Chlorin content of chlorinated lime, titration to determine, 62
liquid, as antiseptic, 64
Chlorinated gauze, 40
lime, as antiseptic, 61
titration to determine chlorin content, 62
saline solutions, 63
Chlormetacresol as antiseptic, 60
Chloroform anesthesia, 116
accidents in, treatment, 116
dangers from, 116
effect on suprarenal capsules, 117
method of administration, 116
mask, extemporized, 88
Chloroform-ether sequence, 119
Chloroform-oxygen anesthesia, 120
Chondroma, 324
bone, 470
Chrome holes, 315
Chromicized catgut, 36
Chrysarobin-serum treatment of psoriasis, 835
Cicatrix, adherent, 225
of muscles, 791
painful, 225
Cigarette drains, 47, 48
Circulation, collateral, tests of efficiency, 390
Circumcision of leg in varicose veins, 452
Circumflex nerve, injuries to, 896
Cirsoid aneurism, 400
Citric acid as antiseptic, 72
Clamp, Michel, for wounds, 187, 189
Claviceps purpurea, 318
Clavicle, dislocation of, 623. See *Dislocations of clavicle.*
excision of, 729
fractures of, 550. See also *Fractures of clavicle.*
resection of, 729
Clavus, 841
Claw hand, 897
Cleanliness in wound infection, 28
Cleansing hands, 173. See also *Sterilization of hands.*
mechanical, of infected wounds, 28
Clips, absorbable metal, for closing blood-vessels, 339
Closed method for ether anesthesia, 106
Closure of wounds, 187. See also *Sutures.*
Clothing, operating, for surgeon, 51, 173
Coagulability of blood, determination of, 458
Coagulants in hemorrhage, 342
Coal-ash dressings, 42
Coaptation sutures, 196
Cocain as local anesthetic, 134
as spinal anesthetic, 156
hydrochlorate as local anesthetic, 135
Cocain-adrenalin for local anesthesia, 135
Coccyx, excision of, 732
Codivilla's method for traction in fractures, 486
Coin catcher, extemporized, 89
Cold, anesthesia from, 154
applications for inflammations, 235
in chronic inflammation, 250
as hemostatic, 339
cream for dry skin, 849
Coley's toxins in inoperable cancer, 332
Collapse during operation, 218
Collargol as antiseptic, 67
Collateral circulation, tests of efficiency, 390
Colles' fracture, 575. See also *Fractures, Colles'.*
Collodion, 53
Colloidal gold test in syphilis, 299
silver as antiseptic, 67
solutions, intravenous infusion with, 347
Color of patient in general anesthesia, 99
Comedo, 845
treatment, 849
Comminuted fractures of lower end of humerus, 570
of patella, 602
Compound Colles' fractures, 579
dislocations, 612
of shoulder, 632
fractures, 518
amputation in, conditions calling for, 520
chloraminated oil in, 519
elevation of temperature after, 520
emergency treatment, 519
filling bone cavities in, 706
first dressing, 518
immobilization in, 520
of fibula, 606
of patella, 603
of shaft of femur, 592
of humerus, 565
of skull, 534
of tibia, 606
with joint wounds, 657
Compression, local, for control of hemorrhage, 370
of artery in aneurism, 381
of nerves, 851
temporary, for suture of arteries, 372
Concussion in basal fractures of skull, 537
Condyles, fractures of, bone grafts in, 515
of humerus, fractures of, 568
Congenital dislocations, 613
of ankle, 618
of elbow, 618

Congenital dislocations of hip, 613
age in treatment, 613
bone grafts in, 783
reduction by manipulation, 613
after-treatment, 615
dangers, 615
technic, 614
by open operation, 616
choice of methods, 617
of knee, 617, 648
of patella, 618
of radius, 618
of shoulder, 618, 634
of wrist, 618
Congestion, hypostatic, 228
irritative, 228
local, hemorrhage in, 359
traumatic, 228
Connective-tissue tumors, benign, 323
Continuous divulsion in fractures, 496
hypodermoclysis, 345
suture, 190
Contracture of psoas parvus muscle simulating appendicitis, 796
Contractured muscles, 793
Contusions, 218
of bones, 467
of bursæ, 819
of muscles, 788
of nerves, 851
of skin, 820
Copper sulphate as caustic, 73
Coproclysis, 344
Coracoid process, fractures of, 556
Corn, 841
Cornu cutaneum, 841
Coronoid process of ulna, fractures of, 573
Corradi-Moore treatment of aneurism, 382
Corrosive sublimate as antiseptic, 59
Cosmetics, skin, 849
Costal cartilages, dislocations of, 623
Cotton, absorbent, 41
Counterirritation for inflammations, 237
Counting sponges and instruments, 172
Coxa valga, operation for, 770
vara, operation for, 770
Cradle, bed, 23, 24
Crane tendon sutures, 37
Cranial nerve, fifth, injuries and diseases of, 881
Cranium. See *Skull*.
Cream, Moynihan's, as antiseptic, 72
Creolin, 66
Creosote as antiseptic, 66
Cresol as antiseptic, 66
Cresol-acetone method of hand sterilization, 174
Cretinism, 322
Crile's pneumatic suit, for prevention of shock, 216
Crucial ligament, relaxed, 653
rupture of, 653
Crushing vessels in hemorrhage, 339
Crutch paralysis in fractures, 527
Cumol method for sterilizing catgut, 34
Cuneiform osteotomy, 713
Cupping, 230
Curative inoculations, 255
Curettage in inoperable cancer, 331
of ulcers, 309
Cushions, air, 23
water, 23
Cutin, 74
Cutting cautery, 80
Cysticercus cutis, 848
Cystomata, 325
bone, 470
Cystotomy, suprapubic, local anesthesia in, 151
Cysts, benign, 325
bone, 709
echinococcus, 326
infected, 326
sebaceous, 845

Dakin-Carrel instillation method for infected wounds, 242
Dakin's antiseptic, 60
formula, 61
for treatment of infected wounds, 242
volumetric analysis, 61
Dandruff, 844
Davison's methods of holding bone transplant in place, 512, 517
Defibrinated blood in hemorrhage, 343
Deformity after fracture of lower extremity of humerus, 571
silver-fork, in Colles' fracture, 575
Degeneration of muscles, 792
ischemic, 793
Dehydration, sterilization by, 30
Delayed union in fractures, 527
Delirium, traumatic, in fractures, 527
tremens with fractures, 526
Deltoid muscle, paralysis of, 795
Denker's operation through upper jaw to reach nasopharynx, 724
Denuded bones, 467
Dermatitis exfoliativa, 826
herpetiformis, 827
infectious eczematoid, 826
venenata, 825
Dermatol as antiseptic, 71
Desiccated vaccine in hydrophobia, 273
Dextrin dressings, 56
Diabetes as factor in operation, 181
Diabetic gangrene, 318
ulcers, 314
Dichloramin-T as antiseptic, 64
in burns, 65, 821
in infected wounds, 247
Dieffenbach's median operation for excision of upper jaw, 722
Dimethylacetal anesthesia, 118
Diphtheria bacillus, wound infection with, 262
Directors, 75
Disarticulations of hip, local anesthesia in, 146
Dishes, 81, 84
Dislocations, 610
after-treatment, 611
blood-vessel injuries in, 611
complications, 611

Dislocations, compound, 612
congenital, 613. See also *Congenital dislocations.*
distortion following, 613
doubtful reductions, 611
edema in, 612
fatal results in, 612
fracture, 521, 611
habitual, 612
infection in, 612
nerve injuries in, 611
obstacles to reduction, 610
of ankle, 649
congenital, 618
of carpometacarpal joints, 639
of carpus, 638
of individual bones, 639
of cartilages of joints, 652
of clavicle, 623
backward, of acromial end, 625
of sternal end, 624
forward, of sternal end, 623
simultaneous, of both ends, 625
subacromial, 625
subcoracoid, 625
upward, of acromial end, 624
of sternal end, 624
of costal cartilages, 623
of elbow, 635. See also *Dislocations of forearm.*
congenital, 618
of ensiform process, 549
of fibula, 649
of fingers, 639
of forearm, 635
anteroposterior, 636
backward, 635
complete outward, 636
complications, 637
congenital, 618
forward, 636
incomplete inward, 635
outward, 636
lateral, old, 638
old unreduced, 637
pathologic, 638
posterior, old, 637
transverse, 636
of great toe, 649
of hip, 640
backward, 641
Bigelow's reduction, 641
Stimson's reduction, 641
bone grafts in, 783
complications, 645
downward and inward, 643
on ischium, 645
everted dorsal, 643
forward, 645
fractures of neck of femur in, 646
of shaft of femur in, 646
habitual, 646
old unreduced, 646
excision of head of femur in, 647
osteotomy of neck of femur in, 647
perineal, 644
through floor of acetabulum, 645
Dislocations, uncomplicated, after-treatment, 645
upward, 645
of knee, 647
backward, 648
congenital, 617, 648
forward, 647
lateral, 648
rotary, 648
of lower jaw, 618
backward, 619
forward, 618
old irreducible, 619
outward, 619
upward, 619
of manubrium, 549
of mediocarpal joint, backward, 638
forward, 638
of metatarsus, 649
of patella, 640
congenital, 618
habitual, bone grafts in, 787
of phalanges, 649
of proximal phalanges of fingers, 639
phalanx of thumb, 639
of radius, backward, 637
congenital, 618
forward, 637
old, 638
outward, 637
of ribs, 623
from vertebræ, 623
of semilunar cartilage of knee-joint, 652
of shoulder, 626
after-treatment, 630
anterior, 626
adduction in, 627
after-treatment, 630
continuous right-angle traction in, 629
downward and outward traction in, 628
foot-in-axilla reduction, 628
fulcrum method in, 629
obstacles to reduction, 629
old, 630
outward rotation in, 627
perpendicular traction in, 629
reduction, natural, 626
complicating injuries, 631
compound, 632
congenital, 618, 634
downward, 630
erect, 630
fracture of anatomic neck of humerus with, 631
of scapula with, 632
of shaft of humerus with, 631
habitual, 632
old unreduced, 634
paralytic, 634
penetration of chest wall in, by head of humerus, 632
posterior, 630
ruptures of muscles and tendons in, 631
subglenoid, 630
upward, 630

Dislocations of tarsus, 649
of ulna, backward, 636
forward, 637
inward, 637
of ulnar nerve, 897
of vertebræ, 620
between atlas and axis, 622
between occiput and atlas, 622
bilateral, 621
complete, 620
dorsal, 622
forward, 621
from ribs, 623
irreducible, 622
lower six cervical, 622
lumbar, 622
of wrist, 638
backward, 638
congenital, 618
forward, 638
lateral, 638
old unreduced, 612
operative treatment, 611
recurrent, 612
reduction, 610
in anesthesia, 610
rupture of muscles in, 612
spontaneous, 613
Dissecting aneurism, 380
forceps, 75
Divulsion, continuous, in fractures, 496
Dodd's non-adherent dressing, 220
Dorsal vertebræ, dislocations of, 622
Dorsalis pedis artery, ligation of, 445
Douche-pan, 24
Doyen's bone saw, 691
Drainage in abscess, 252
lymphatic, 463
materials, 45
of wounds, 204
tubes, 44, 45
glass, 46
rubber, 45
self-retaining, 46
Vance's, 47
Drains, cigarette, 47, 48
gauze, 47
non-absorbent, 47
wick, 47
Dressings, 205
asbestos absorbent wool, 42
cement, 56
charcoal, 42
coal ash, 42
dextrin, 56
flax, 41
Florida moss, 42
for abscess, 252
for carbuncle, 253
for ulcers, 308
gauze, 39. See also *Gauze dressings.*
glue, 56
gum mixtures for, 57
Indian hemp, 42
lamb's wool, 42
magnesite, 57
materials for, 39
Dressings, non-adherent, 220
oakum, 41
paper wool, 42
peat, 42
sawdust, 42
subsequent, 211
tow, 41
turf-moss, 42
wood fiber, 42
wadding 42
zinc-gelatin, in varicose ulcers, 310
Drop-foot, 898
infantile paralysis with, silk ligaments in 802
Dry air sterilization of rubber gloves, 52
gangrene, 316
heat method for catgut, 36
skin, 844
Dupuytren's splint in Pott's fracture, 606
Dwarfism, 322

Ear, operations on, by local anesthesia, 143
Echinococcus cysts, 326
Eck's fistula, 458
Ecraseur, 79
Ecthyma, 829
Eczema, 830
acute, 831
erythematous, 831
bichlorid, 833
chronic dry, 831
in children, 833
local treatment, 831
of anus, 832
of eyelids, 832
of face, erythematous, 832
of hands, 833
of legs, 832
of lips, 832
of palms and soles, hyperkeratotic, 833
of scalp, 832
of scrotum, 832
of vulva, 832
purulent, 832
vaccines in, 832
vesicular, 831
with varicose veins, 448
Eczematoid dermatitis, infectious, 826
Eczematous ulcers, 314
Edema in dislocations, 612
in fractures, 524
Edematous ulcers, 314
Efferent nerves, 861
Ehrlich's "606." See *Salvarsan.*
neosalvarsan, 294
Elastic extension in fractures, 495
Elbow, ankylosis of, arthroplasty for, 762
dislocations of, 635. See also *Dislocations of forearm.*
excision of, 742. See also *Excision of elbow.*
fractures of, 565
sprains of, 652
tuberculosis of, 679
Electric light treatment of infected wounds, 241
motor or bone grafting, 691

Electricity as hemostatic, 339
in aneurism, 381
in chronic inflammation, 250
Electrocautery, 80, 83
Electrolysis in aneurism, 382
in angioma, 453
Elephantiasis, 462
fibrolysin in, 464
of scrotum, 464
treatment, 463
Elevation in hemorrhage, 341
of limbs for varicose veins, 448
of part in inflammation, 237
of periosteum, 688
Eliminants, gas, 226
Embolic gangrene, 320
Embolism, 454
air, 447
axillary, 455
fat, 456
of common iliac artery, 455
of femoral artery, 455
of pulmonary artery, 457
treatment, 455
Emergency instruments, 87
splints, 472
Emphysema, malignant, 270
surgical, in fractures, 525
traumatic, 820
Emphysematous gangrene, 270
Emulsion, iodoform as antiseptic, 69
Enchondroma of bones, 709
Endo-aneurismorrhaphy, 385
Endothelioma, 324
Endothracheal insufflation with nitrous-oxide oxygen, 122
End-to-end anastomosis of arteries, 374
Ensiform process, dislocations of, 549
Enteroclysis, 344
neosalvarsan by, in syphilis, 297
salvarsan by, in syphilis, 297
Enterostomy, purse-string suture in, 203
Enucleation, subcutaneous, of varicose veins, 452
Environment as factor in surgical treatment, 22
Epicondyles of humerus, fractures of, 568
Epidural sacral anesthesia, 162
Epilepsy, removal of cervical sympathetic ganglia in, 899
Epiphysis, caries and necrosis of, filling bone cavities in, 706
loss of, operations to compensate, 769
lower, separation, in fractures of lower end of femur, 594
separation of, in fractures, 524
Epithelial tumors, benign, 324
Epithelioma, adamantine, 709
Erasion, 710
in knee-joint, 710
of joints, 738
of knee-joint, 752
Ergot poisoning, gangrene from, 318
Erysipelas, 262
curative effect, 264
neonatorum, 263
phlegmonous, 262
Erysipelas tincture of iodin in, 69
toxins in inoperable cancer, 332
treatment, 263
ultra-violet rays in, 263
vaccines in, 264
Erysipeloid, 264
Erythema intertrigo, 825
multiforme, 825
Esmarch's bandage, 56
for inflammation, 229
operation for ankylosis of lower jaw, 726
Esophagus, operations on, local anesthesia for, 144
Ether anesthesia, 104
after-effects, 115
aspiration pneumonia in, 105
blood-pressure in, 105
by intramuscular injections, 115
closed method, 106
combined closed and open method, 108
confined vapor method, 110
effects, 105
hallucinations in, 105
hydrobromic, 118
intravenous, 114
methods, 105
methyl, 118
methylene, 118
open drop method, 107
pharyngeal insufflation in, 110
primary method, 110
rectal, 110
vapor, 110
vapor method, 109
effects of, 105
for abscesses, 235
fusil, 104
inhalers, 106, 107
treatment of infected wounds, 248
Ether-oxygen anesthesia, 120
Ethyl bromid anesthesia, 118
chlorid anesthesia, 117
as local anesthetic, 154
chlorid-ether sequence, 119
hydrate as antiseptic, 72
Eucain as local anesthetic, 135
Eucalyptol as antiseptic, 72
Eupad as antiseptic, 62
Europhen as antiseptic, 70
Eusol as antiseptic, 62
Evaporating lotions for inflammations, 237
Excision of ankle, 753
by bilateral incisions, 754
by external curved incision, 754
by transverse external incision, 755
of astragalus, 735, 736
of bones, 717
of calcaneum, 734, 736
of clavicle, 729
of coccyx, 732
of elbow, 742
by long external incision, 745
by posterior curved incision, 746
median incision, 744
by radial incision, 743
by right angular incision, 744
for ankylosis, 745

Excision of elbow, osteoplastic, 745
partial, 745
of fibula, 734
of first metatarsophalangeal joint, 755
of hip, 748
by anterior incision, 749
by bow incision, 749
by curved incision, 749
by right angular curved incision, 749
by straight external incision, 748
of humerus, 730
of shaft, 731
total, 731
of joints, 738
of knee, 749
operation, 750
without opening joint, 751
of lower jaw, 724
of metacarpal bones, 731
of metatarsal bones, 737
of patella, 732
of phalanges, 731
of radius, 731
of scapula, 730
of shaft of humerus, 731
of short internal incision, 745
of shoulder, 741
by curved osteoplastic incision, 742
by deltoid flap, 742
by division of acromion through posterior incision, 742
by transverse incision, 742
through anterior incision, 741
through vertical incision, 742
of tarsal bones, 734
of tibia, 733
of ulna, 731
of upper jaw, 717
by external incision, 721
by Langenbeck's cheek-flap operation, 722
by mediolateral incision, 718
Dieffenbach's median operation for, 722
Malgaigne's method, 722
subperiosteal, 722
of whole of lower jaw, 725
of wrist, 746
by single dorsal incision, 747
by two dorsal incisions, 746
through bilateral incisions, 747
simultaneous, of both upper jaws, 722
Exemia, 213
Exophthalmic goiter, removal of cervical sympathetic ganglia in, 899
Exostosis bursitis, 709
Explosive bullets, wounds from, 222
Exposure of joints, 738
Extemporized splints, 474
Extension, continuous, in fractures, 488
elastic, in fractures, 495
nail, in fractures, 495
pillow, in fractures, 493
pneumatic, in fractures, 494
Extensor proprius hallucis, transplantation of, for tibialis anticus, 809
Extraction of teeth by local anesthesia, 141
Extremities, operations on, prevention of shock in, 215
upper, operations on, local anesthesia in, 145
Exuberant ulcers, 314
Exudative synovitis, 658
Eye in general anesthesia, 99
Eyelids, eczema of, 832

FACE cream, greaseless, 849
operations on, local anesthesia for, 140
Facial artery, ligation of, 412
muscles, spasm of, 888
nerve. See *Fifth nerve.*
paralysis, 881
accessorius-facial nerve grafting in, 885
Ballance's operation in, 887
grafting hypoglossal nerve in, 882
spinal accessory nerve in, 882
hypoglossal-accessorius-facial nerve grafting in, 886
hypoglossal-facial nerve grafting in, 883
Family peculiarities as factor in surgical treatment, 18
Farabeuf's operation for excision of tarsal bones, 735
Fascia, 818
for reconstruction of tendon, 803
in hemorrhage, 342
living, as sutures, 38
Fat, animal, effect of, on leukocytosis, 20
embolism, 456
filling bone-cavities with, 704
in hemorrhage, 342
Faulty union in fractures, 527
Favus, 838
Fecal fistula, bismuth paste injections in, 307
Female generative organs, operations on, local anesthesia in, 152
Femoral aneurism, 398
artery, anatomy, 434
compression of, for hemorrhage, 367
embolism of, 455
ligation of, 431
for varicose veins, 453
indications, 436
hernia, operations on, local anesthesia in, 150
Femur, excision of head, in old unreduced hip dislocations, 647
fractures of, 583
head, 583
in newborn, 530
lesser trochanter of, 583
lower end, 593
intra-articular, 653
part of shaft, 594
neck, 583. See also *Fractures of neck of femur.*
shaft, 588. See also *Fractures of shaft of femur.*
side splint for, 492
supracervical, of great trochanter, 583
traction in, 490
internal condyle, oblique division of, 715
osteotomy of, 713

Femur, osteotomy of, in knee tuberculosis, 677
lower end, 714
neck, 713
in old unreduced hip dislocations, 647
supracondyloid, from inner side, 715
from outer side, 715
upper end, 713
resection of, 732
restoring head of, by bone graft of astragalus, 785
Fenestra in plaster-of-Paris splints, 481
Fermentation, intestinal, prevention of, 20
Fever from wounds, 213
surgical, 255
aseptic, 259
Fibrolysin in elephantiasis, 464
Fibroma, 324
of bone, 470
medullary, 709
periosteal, 709
Fibrositis, chronic, 865
Fibrous union in fractures, 528
Fibula, dislocations of, 649
excision of, 734
fractures of, 603
after-treatment, 608
lower end, 606
old, with vicious union, 608
shaft, 603, 606
upper end, 603
resection of, 734
Fifth nerve, division of, at entrance to bone, in neuralgia, 873
of second and third divisions, in neuralgia, 876
of second division, at foramen rotundum, in neuralgia, 872
of third division, at base of skull, in neuralgia, 874
by temporary resection of zygoma, in neuralgia, 875
in neuralgia, 873
injuries and diseases of, 881
neuralgia of, 877
paralysis of, neuropathic, 881. See also *Facial paralysis*.
Figure-of-eight sutures, 198
double, 198
Filaria sanguinis hominis, lymphatic obstruction from, 462
Filling materials, 74
Finger cots, rubber, 53
Fingers, dislocations of, 639
proximal phalanges of, 639
Fistula, 304
chalk paste in, 308
Eck's, 458
occlusion treatment, 304
tuberculous, 282
Fixation, direct, of fragments in fractures, 502
Flannel bandages, 55
Flat sponges, 44
Flat-foot, arthrodesis in, 739
Flavin as antiseptic, 65
Flax dressings, 41
Fleas, bites of, 275
Flexor hallucis longus tendons, tenotomy of 815
Flies, bites of, 275
Florida moss dressings, 42
Fomentations, hot, in abscess, 251
Foot, trench-, 319
Forceps, dissecting, 75
hemostatic, 77
mouse-tooth, 75
tongue, for general anesthesia, 95
Forearm, dislocations of, 635. See also *Dislocations of forearm*.
fractures of, bone grafts in, 512
in newborn, 531
sterilization of, 173
Foreign bodies in wounds, *x*-ray for removal, 223
wounds with, 222
Formaldehyd as antiseptic, 68
polymerized, as antiseptic, 68
Formalin, 68
method for sterilizing catgut, 36
Formalin-glycerin injections in joint tuberculosis, 281, 664
wounds, 655
Formalin-iodin method for sterilizing catgut, 36
Formic aldehyd as antiseptic, 68
Fourth-of-July tetanus, 270
Fractional sterilization, 28
Fractured cartilages, 653
Fractures, 472
Albee's bone grafts in, 507
ambulant treatment, 522
apparatus for moving bones in, 497
for traction, 485
bone cylinders in, 507
ferrules in, 507
grafting in, 509. See also *Bone grafts*
Buck's extension in, 488
callus, 472
Codivilla's method of traction in, 486
Colles' compound, 579
dislocation with, 579
dressing, 576
imperfect reduction in, 579
irreducible displacement in, 578
method of reduction, 576
silver-fork deformity in, 575
sprain with, 579
vicious union in, 579
with anterior displacement of lower fragment, 579
without displacement, 578
complicating dislocations, 611
complications of, 524
compound, 518. See also *Compound fractures*.
condition of skin, 476
continuous divulsion in, 496
extension in, 488
traction in, 487
crutch paralysis in, 527
deformity from, correction, 474
delayed union in, 527
delirium tremens with, 526
direct fixation of fragments in, 502

Fractures, dislocations complicating, 521
displaced bones in, 524
edema in, 524
elastic extension in, 495
elevation of temperature after, 520
excessive callus in, 525
faulty union in, 527
fibrous union in, 528
gangrene in, 525
hypostatic congestion of lungs in, 525
immediate reduction, 475
treatment, 472
immobilization of fragments, 476
impaction in, 524
in newborn, 529
in old persons, 526
intrauterine, 529
involving joints, 518
joint stiffness in, 525
lacerated muscles in, 524
length of time for healing, 523
lymphedema in, 524
massage in, 500
metallic bands in, 506
plates in, 507
muscular atrophy in, 525
spasm after, 525
nail extension in, 495
nailing fragments in, 506
necrosis of bones in, 525
nerve injury in, 524
non-union in, 529
obstacles to reduction, 475
of acromion process, 556
of alveolar process of jaw, 543
of anatomical neck of humerus, 557
with shoulder dislocation, 631
of astragalus, 608
of body of scapula, 556
of carpus, 579
of clavicle, 550
bandage and adhesive plaster treatment, 551
bone graft in, 511
dressings for, 554
in newborn, 530
operative treatment, 565
recumbent treatment, 550
rest treatment, 550
Sayre's dressing for, modified, 552
of condyles, bone grafts in, 515
of coracoid process, 556
of coronoid process of ulna, 573
of elbow, 565
of external condyle of humerus, 568
epicondyle of humerus, 568
of femur, 583
head of, 583
in newborn, 530
lesser trochanter of, 583
lower end of, 593, 594, 653
neck of, 583
shaft of, 588
side splint for, 492
supracervical, of great trochanter, 583
supracondyloid, 594
traction in, 490
Fractures of fibula, 603
after-treatment, 608
compound, 606
lower end of, 606
old, with vicious union, 608
shaft of, 603, 606
upper end of, 603
of forearm, bone grafts in, 512
in newborn, 531
of head of femur, 583
of humerus, 556
of radius, 572
of scapula, 556
of humerus, 556
anatomical neck of, 557
with shoulder dislocation, 631
bone graft in, 511
epicondyle of, 568
external condyle of, 568
head of, 556
in newborn, 529
internal condyle, 568
epicondyle, 568
lower end, 565–571
separation of lower epiphysis, 571
shaft of, 560
supracondyloid, 567
low, 571
surgical neck of, 558
tuberosities of, 557
upper end of, 556
of hyoid bone, 548
of internal condyle of humerus, 568
epicondyle of humerus, 568
of jaw, 542
interdental moulded splint in, 542
lower, 543
interdental splint in, 544
Matas' splint in, 545
plaster-of-Paris bandage in, 544
wiring in, 545
upper, 542
of leg in newborn, 531
of lesser trochanter of femur, 583
of lower end of femur, 593, 653
gangrene of leg in, 595
injury of popliteal blood-vessels in, 595
separation of lower epiphysis in, 594
of fibula, 606
of humerus, 565
ankylosis after, 571
articular process, 571
comminuted, 570
deformity after, 571
degree of bony displacement, 566
of shaft of femur, 594
jaw, bone grafts in, 518
of malar bone, 540
of malleolus, bone grafts in, 516
of metacarpus, 579
of metatarsus, 608
of nasal bones, 539
hematoma in, 539
lateral displacement in, 539
rubber tube splint in, 539

Fractures of nasal septum, 540
of neck of femur, 583
abduction method in, 585
bone grafts in, 512
combined longitudinal and transverse traction in, 583
impaction in, 585
in children, 587
in hip dislocations, 646
in old persons, 586
operative treatment, 587
time required for union, 586
without impaction, 583
of radius, 572
of scapula, 556
of olecranon, bone grafts in, 511
fibrous union in, 573
of os calcis, bone grafts in, 517
of patella, 596
ambulant treatment, 597
bone grafts in, 516
comminuted, 602
compound, 603
multiple, 602
nonoperative treatment, 596
operations on, local anesthesia for, 147
operative treatment, 598, 602
masssge in, 601
of old cases, 602
passive motion, 601
suturing in, 599
technic, 599
with slight separation, 602
of pelvis, 582
of phalanges, 580
of radius, 572
head of, 572
neck of, 572
shaft of, 573
of ribs, 549
of scapula, 556
body of, 556
head of, 556
neck of, 556
spine of, 556
upper angle of, 556
with shoulder dislocation, 632
of sesamoid bone of thumb, 582
of shaft of femur, 588
amount of weight to use, 588
compound, 592
consolidation in, time of, 589
double lateral splint in, 592
hip splints in, 591
in hip dislocations, 646
in upper part, 590
operative treatment, 591
permanent dressing, 588
plaster-of-Paris case in, 591
suspension splint in, 591
temporary splint, 588
transverse, 590
variations in, 589
vertical extension in, 592
of fibula, 603, 606
of humerus, 560
compound, 565
Fractures of humerus, Penhallow's splint in, 561
scaffold splint in, 564
with much displacement, 563
with shoulder dislocation, 631
with slight displacement, 562
of radius, 573
of tibia, 603
of ulna, 573, 574
of skull, 532
basal, 534
concussion in, 537
immobilization in, 535
lumbar puncture in, 536
operative treatment, 536
trephining in, 536
with compression symptoms, 537
with meningeal infection, 537
compound, 534
depressed, 534
with symptoms of brain compression, 534
without depression or symptoms of brain injury, 534
gutter, 532
punctured, through orbit, 537
simple depressed, 532
vault and base, 537
simple linear, with symptoms of brain compression, 532
of spine of scapula, 556
of tibia, 654
of sternum, 548
of styloid process of ulna, 579
of surgical neck of humerus, 558
of tarsus, 608
of thumb, 582
of tibia, 603
after-treatment, 608
compound, 606
old, with vicious union, 608
shaft of, 603
spine of, 654
upper end of, 603
of tuberosities of humerus, 557
of ulna, 572
shaft of, 573, 574
styloid process of, 579
of upper angle of scapula, 556
end of fibula, 603
of humerus, 556
of tibia, 603
of vertebræ, 537
immobilization in, 538
with compression, 538
of zygoma, 540
operative treatment, 502
pain in, 525
paralysis in, 525
pegging fragments in, 506
pillow extension in, 493
pneumatic extension in, 494
Pott's, 606
reduction of, artificial leverage in, 476
screws in, 507
separation of epiphyses in, 524
splints for, 477

Fractures, subcervical, of great trochanter of femur, 583
supracervical, of great trochanter of femur, 583
surgical emphysema in, 525
suturing bones in, 503
swelling in, 525
temporary traction in, 485
traction in, measurement of legs in, 493
transverse traction in, 498
traumatic delirium in, 527
ulceration in, 525
weight and pulley traction in, 487
wire traction from skin in, 493
wiring bones in, 503
Zuppinger's lever traction frame, 494
Fragilitas ossium, 471
Frambesia tropica, 303
salvarsan in, 303
Freckles, 840
Fresh air as factor, 21
in hemorrhage, 344
in tuberculosis, 278
Frost-bite, 826
antitetanic serum in, 265
gangrene from, 318
Fulguration in inoperable cancer, 332
Fulminating infective gangrene, 317
Fungous ulcers, 314
Fungus disease of India, 273
Furuncles, 253, 827
vaccines in, 253, 829
Fusil ethers, 104

Gad-flies, bites of, 276
Gall-bladder, operations on, local anesthesia in, 150
purse-string suture of, 202
Galvanism in neuralgia, 864
Ganglia, cervical sympathetic, injuries to, 898. See also *Cervical sympathetic ganglia.*
Ganglion tumor, 818
Gangrene, 304, 315
arterial occlusive, 317
diabetic, 318
dry, 316
embolic, 320
from ergot poisoning, 318
from frost-bite, 318
from obliterating angeitis, 316
from poisons, 320
fulminating infective, 317
hospital, 318
hot-air treatment, 315
in fractures, 525
inflammatory, 317
malignant, 270
moist, 317
nonsenile, 320
of leg in fractures of lower end of femur, 595
of muscle, 791
phagedenic, 319
phenol, 320
postfebrile, 320
presenile, 320
Gangrene, Raynaud's, 318
rules for amputation in, 316
senile, 317
sloughing, 319
suction treatment, 315
traumatic, 317
trophic, 320
Gangrenous cellulitis, 318
stomatitis, 319
Gaping wounds, 212
Gas bacillus infection, 270
Menciere's solution in, 271
Morestin's mixture in, 271
wounds infected with, 222
eliminants, 226
Gas-ether sequence, 118
Gasserian ganglion, alcohol injection of, in trifacial neuralgia, 869
Gastro-enterostomy, local anesthesia in, 150
Gastrostomy, purse-string suture in, 203
Gauss' artery press in hemorrhage, 366
Gauze, 39
Balsam-of-Peru, 40
bandages, 55
bichlorid, 40
bismuth, 40
boric acid, 41, 67
borosalicylic, 41
chloretone, 41
chlorinated, 40
drains, 47
iodoform, 40
sticky, 40
kephalin, 41
medicated, 39
paraffined, 41
phenol, 40
sponges, 43
sterilization of, 39
zinc oxid, 41
Gelatin in hemorrhage, 343
Genitals, preparation of, for operations, 180
Genito-urinary fistulas, bismuth paste injections in, 308
organs, operations, local anesthesia for, 157
Genu valgum, osteotomy for, 714
varum, deformity in, bone-grafts for, 787
Giant-cell sarcoma of long bones, 707, 709
Giantism, 322
Glanders, 273
Glands of skin, diseases of, 844
Glass drainage tubes, 46
Glaucoma, removal of upper cervical sympathetic ganglion in, 898
Gloves, rubber, 52
care of, 174
method of adjusting, 174
sterilization of, 52. See also *Sterilization.*
Glucose injections, 20, 21
Glue dressings, 56
Gluteal artery, ligation of, 430
Glycerin, 58
method for sterilization of rubber gloves 52
phenolized, as antiseptic, 66

Glycerin treatment of infected wounds, 241
Glycerin-formalin injections in tuberculosis of joints, 281, 664
in wounds of joints, 655
Gnats, bites of, 275
Goldthwait's thumb splint, 582
Gonorrheal arthritis, 660
tenosynovitis, 817
Gowns, nurses', 51
Gracilis, tendons of, tenotomy of, 815
Grafting, bone. See *Bone grafts.*
nerve, 857
in facial paralysis, 882
results, 859
tendon, 805
Grafts, bone, 509. See also *Bone grafts.*
Granulating wounds, 220
Grape sugar injections, 20
Gravity ischemia with elastic constriction for control of hemorrhage, 369
Greaseless face cream, 849
Gum acacia in saline infusion, 348
mixtures for dressings, 57
Gummatous ulcerations, treatment, 302
Gunshot wounds, 222
of joints, 656
Gutta-percha solutions, 53
Gutter fractures of skull, 532

Habits as factor in surgical treatment, 18
Habitual dislocations, 612
of hip, 646
bone grafts in, 783
of patella, bone grafts in, 787
of shoulder, 632
Hackenbruch's fracture clamps, 497
Hair, atrophy of, 847
diseases of, 846
human, for suturing arteries, 372
superfluous, 846
Halazone as antiseptic, 63
Hallucinations from ether, 105
Halogen derivatives of phenol as antiseptics, 60
Hammer-toe, arthrodesis in, 739
Hamstring tendons, tenotomy of, 815
Hand sponges, 43
Hands, chapped, 849
eczema of, 833
excessive sweating of, treatment, 849
extensors of, paralysis of, tendon transplantation in, 812
muscles moving, 893
sterilization of, 173. See also *Sterilization of hands.*
Hard skin, 841
Harrington's solution as antiseptic, 59
Harrison's drainage tube, 46, 47
Hartwell's method of blood transfusion, 352
Head, arteries of, ligation of, incisions for, 404
lowering of, in hemorrhage, 344
operations on, local anesthesia for, 140
prevention of shock, 215
preparation of, for operation, 180
tetanus, 270
Heart, massage of, in general anesthesia, 99
Heat as hemostatic, 339
sterilization by, 28
Heliotherapy in infected wounds, 241
in tuberculosis, 280
of joints, 664
of knee, 675
in varicose ulcers, 312
Hematoma in fractures of nasal bones, 539
subungual, 847
Hemolysis in blood transfusion, 348
testing for, 355
Hemophilia, as factor in operation, 181
hemorrhage in, 359
Hemophiliac joints, 682
Hemorrhage, 334
acupressure in, 341
adding fluids to body in, 344
adrenalin chlorid in, 341
anemia from, 343
angiotribe in, 339, 340
antidiphtheritic serum in, 342
antistreptococcic serum in, 342
artificial local anemia in, 367
astringents in, 341
blood in, 342
blood transfusion in, 343, 348
blood-serum in, 342
calcium in, 343
cautery in, 339
coagulants in, 342
cold in, 339
compression in, artery press for, 366
of arteries in, 360
control of, constriction of limb for, 367
gravity ischemia with elastic constriction in, 369
local compression for, 370
sequestration of blood for, 369
crushing vessels in, 339
defibrinated blood in, 343
elevation in, 341
electricity in, 339
fascia in, 342
fat in, 342
fresh air in, 344
gelatin in, 343
heat in, 339
impromptu tourniquet in, 335
in hemophilia, 359
in infection, 359
in jaundice, 359
in local congestion, 359
in pernicious anemia, 360
in purpura, 360
in scurvy, 360
in traumatic asphyxia, 360
in wounds, 212
kephalin in, 342
ligature in, 335
live steam in, 339
lowering of head in, 344
mass-ligature in, 337
Momburg's belt constriction in, 363
muscle in, 342
natural arrest of, 334
postoperative prevention, 181
pressure in, 334

Hemorrhage, reactionary, 358
secondary, 358
surgical arrest, 334
styptics in, 341
thrombin in, 342
thromboplastin in, 342
transfusion of blood in, 348
treatment, rules and suggestions for, 370
torsion in, 341
Hemostatic forceps, 77
Hereditary syphilis, 301
Hernia, femoral, operations on, local anesthesia in, 150
inguinal, operations on, local anesthesia in, 150
of muscle, 789
umbilical, operations on, local anesthesia in, 150
ventral, operations on, local anesthesia in, 150
Heron tendon sutures, 37
Herpes progenitalis in syphilis, treatment, 302
simplex, 829
zoster, 830
Heteroplastic bone flaps, 700
for filling defects, 700
bone grafts, 772
nerve bridging, 855
transplantation, 857
Hiccough, postoperative, 226
Hip, ankylosis of, arthroplasty in, 765
osteotomy in, 713
dislocations of, 640. See also *Dislocations of hip.*
congenital, 613. See also *Congenital dislocation of hip.*
excision of, 748. See also *Excision of hip.*
paralytic relaxation of, arthrodesis in, 739
splints in fractures of shaft of femur, 591
sprains of, 652
tuberculosis of, 665. See also *Tuberculosis of hip.*
Hives, 827
Hodgen's splint in impacted fracture of neck of femur, 585
Hodgkin's disease, 464
x-rays in, 465
Holders, needle, 79
sponge, 79
Holes, chrome, 315
Holocain hydrochlorid as local anesthetic, 137
Homoplastic nerve transplantation, 857
Horn, 841
Horsehair sutures, 37
Horsley's clamp for lateral anastomosis of arteries, 378
Hospital bed, 22, 23
gangrene, 318
proper ventilation of, 21
Hot air in gangrene, 315
treatment of suppurating wounds, 187
applications for inflammation, 233
in chronic inflammations, 249
water sterilizer, 29
Housemaid's knee, 819
Humerus, anatomical neck, fractures of, 557
excision of, 730
shaft, 731
total, 731
fractures of, 556. See also *Fractures o humerus.*
lower extremity, 560. See also *Fractures of lower extremity of humerus.*
shaft, 560. See also *Fractures of shaft of humerus.*
head of, penetration of chest wall by, in shoulder dislocations, 632
osteosarcoma of head and neck, 706
resection of, 730
surgical neck, fractures of, 558
tuberosities, fractures of, 557
upper extremity, fractures of, 556
Hunter's canal, ligation of femoral artery in, 436
Hychlorite as antiseptic, 63
Hydrargyri chloridum corrosivum in syphilis, 285
iodidum flavum in syphilis, 285
Hydrargyrism in syphilis, 289
Hydrargyrum oleatum in syphilis, 286
Hydrobromic ether anesthesia, 118
Hydrochloric acid as antiseptic, 72
Hydrochlorid of quinin as antiseptic, 71
Hydrogen peroxid as antiseptic, 68
Hydrophobia, 273
desiccated vaccine in, 273
Pasteur treatment, 273
Hydrotherapy in burns of skin, 822
in syphilis, 298
Hyoid bone, fractures of, 548
Hypercapnia in anesthesia, 123
Hyperemia, Bier's, 229–232. See also *Bier's hyperemia.*
pulmonary, postoperative, 227
Hyperidrosis, 844
of hands, treatment, 849
Hypertonic solutions, injection of, 138
treatment of infected wounds, 241
Hypertrichosis, 846
Hypertrophic skin diseases, 840
Hypertrophy of nail, 848
Hypnotic anesthesia, 126
Hypochlorite of potassium as antiseptic, 64
of sodium as antiseptic, 64
solution, method of making, 62
Hypodermic narcotic agents, 123
Hypodermoclysis, 344
continuous, 345
Hypoglossal nerve, grafting of, in facial paralysis, 882
injuries and diseases of, 892
Hypoglossal-accessorius-facial nerve grafting in facial paralysis, 886
Hypoglossal-facial nerve grafting in facial paralysis, 883
Hypostatic congestion, 228
of lungs in fracture, 525
Hyposulphite of calcium as disinfectant, 61
Hypotonic solutions, injection of, 138

Ice as anesthetic, 154
Ice-bag, 236

Ichthargan as antiseptic, 67
Ichthoform as antiseptic, 73
Ichthyol as antiseptic, 73
silver as antiseptic, 67
Ichthyol glycerin as antiseptic, 73
Ichthyosis, 842
Iliac artery, common, embolism of, 455
ligation of, 426
extraperitoneal, 426
compression of, for hemorrhage, 367
external, aneurism of, 398
ligation of, 429
internal, aneurism of, 398
compression of, for hemorrhage, 367
ligation of, 430
Immobilization for infected wounds, 222
in basal fractures of skull, 535
in compound fractures, 520
in fracture of vertebræ, 538
in tuberculosis of hip, 666, 668
of knee-joint, 674
of fragments after fracture, 476
Impaction in fractures, 524
Impervious protective materials, 52
Impetigo contagiosa, 829
Implantation of nerves, 857
results, 859
Incised wounds, 219
of joints, infected, 655
India, fungus disease of, 273
Indian hemp dressings, 42
Indirect blood transfusion, 353
Indolent ulcers, 312
Indurated ulcers, 313
Infantile paralysis, arthrodesis in, 738
with drop-foot, silk ligaments in, 802
Infected cysts, 326
wounds, 27, 28, 211, 237
artificial hyperemia in, 28
Bacillus diphtheriæ in, 262
cleanliness of, 28
gas bacillus in, 222
heliotherapy in, 241
immobilization for, 222
iodized starch for, 242
Javel water in, 64, 247
Labarraque's solution in, 64
mechanical cleansing in, 28
of joints, incised, 655
poultice in, 28
putrefactive organisms in, 212
rest treatment, 187
sources of, 28
staphylococci in, 212
treatment, 186, 237
antiseptic, 242
bipp paste, 248
bismuth paste, 248
chloramin, 242
chloraminated oil, 247
chlorazene, 242, 247
Dakin's antiseptic, 242
Dakin-Carrel instillation method, 247
dichloramin, 247
electric light, 241
ether, 248
Infected wounds, treatment, glycerin, 241
hot peroxid-phenol, 247
hypertonic, 241
lactic acid, 241
magnesium hypochlorite method, 247
magnesium sulphate, 248
open, 240
physiologic, 239
potassium hypochlorite, 247
salt pack, 241
soap, 248
sodium hypochlorite, 247
with Bacillus bulgaricus, 241
Infection from outside body, 27
from within body, 27
gas bacillus, 270
hemorrhage in, 359
joint, vaccines in, 257
of muscles, 791
pyocyaneus, 262
resistance to, as factor in surgical treatment, 26
skin, 825
sodium succinate in, 258
streptococcus, 262
surgical, 255
with Bacillus aërogenes capsulatus, 271
wound, 27. See also *Infected wounds.*
Infectious eczematoid dermatitis, 826
Infective arteritis, 380
arthritis, acute, 658
bursitis, 819
inflammation of wounds, 28
lymphoma, 464
x-rays in, 465
myositis, 791
neuritis, acute, 862
synovitis, acute, 658
tenosynovitis, 817
Infiltration anesthesia, 127
general, in local anesthesia, 132
Inflamed patellar pad, 653
ulcers, 312
Inflammation, 228
acute, 228
rest treatment, 229
Bier's hyperemia in, 229
chronic, 249
Bier's hyperemia for, 232
cold applications in, 250
electricity in, 250
massage in, 249
nourishment in, 249
passive motion in, 249
rest in, 250
seton in, 250
skin irritation in, 250
suction-traction massage in, 250
vibration in, 249
cold applications for, 235
counterirritation for, 237
dietetic treatment, 235
elevation of part in, 237
evaporating lotions for, 237
hot applications in, 233
infective, 228

Inflammation, inhibitive treatment, 235
local antiseptic treatment, 234
natural treatment, 228
of nail, 848
skin, 825
Inflammatory gangrene, 317
Influenza, arthritis in, 660
Infolding suture, 201
Infusion, arterial, local anesthesia by, 134
saline. See *Saline infusion.*
sugar, 348
venous, in local anesthesia, 132
Inguinal hernia, operations on, local anesthesia in, 150
Inhalers, ether, 106, 107
Injections, nutrient, 20
proteid, 21
Injuries of nails, 847
Inlay bone graft, method of holding, 774
Innominate artery, aneurism of, 399
ligation of, 403
indications for, 406
Inoculations, curative, 255
protective, 255
Inoperable cancer, 331
Insects, bites and stings of, 275
infection from, 27
Instruments, 75
arrangement of, at operations, 169
bone, extemporized, 89
counting of, 172
emergency, 87
nurse in charge of, 169
room for, 167
sterilization of, 89
table for, 169
Insufflation, endotracheal, with nitrous-oxid oxygen, 122
pharyngeal in ether anesthesia, 110
Intercostal nerves, injuries of, 897
neuralgia, 897
Interdental moulded splints in jaw fractures, 542, 544, 546
Interlocking suture, 201
Intermittent anesthesia, 101
Internal diseases, 17
natural tendency of, 17
Interrupted sutures, 187
Interstitial injections of oxygen, 358
Intestinal fermentation, prevention of, 20
toxemia, 259
Intestines, preparation of, for operation, 180
Intra-abdominal saline infusion, 346
Intra-articular fracture of lower end of femur, 653
Intracellular saline infusion, 346
Intramuscular injections of ether, 115
of magnesium sulphate in tetanus, 269
of salvarsan in syphilis 297
of mercury in syphilis, 286
Intraspinal injection of magnesium sulphate, 161
in tetanus, 268
Intratracheal anesthesia, 125
Intra-uterine fractures, 529
Intravenous general anesthesia, 164
with magnesium sulphate, 164
Intravenous infusion into sagittal sinus in children, 347
saline, 346
with colloidal solutions, 347
injections, nutrient, 20
of magnesium sulphate in tetanus, 269
of oxygen, 357
Intraventricular injection of salvarsan in paresis, 296
Inunctions, mercurial, in syphilis, 286
Invagination method of suture of artery, 376
Iodin for preparation of operative field, 177
in soiled wounds, 186
in syphilis, 290
method for sterilizing catgut, 35
of hand sterilization, 174
powder, 69
tincture of, as antiseptic, 68
Iodism in syphilis, 291
Iodized starch for infected wounds, 242
Iodoform as antiseptic, 69
emulsion as antiseptic, 69
gauze, 40
sticky, 40
substitutes, 70
wicking, 40
Iodoform-balsam as antiseptic, 70
Iodoform-collodion as antiseptic, 69
Iodoform-ether as antiseptic, 69
Iodoform-glycerin as antiseptic, 69
Iodoformin as antiseptic, 70
Iodoformogen as antiseptic, 70
Iodoformol as antiseptic, 70
Iodol as antiseptic, 70
Iodomuth as antiseptic, 70
Iodosyl as antiseptic, 70
Iodozen as antiseptic, 70
Irish moss lubricant, 58
Iron chlorid as antiseptic, 72
sulphate as antiseptic, 73
wire sutures, 38
Irrigation apparatus, extemporized, 88
receptacles, 82
Irritable spine, 681
ulcers, 313
Irritative congestion, 228
Ischemia, gravity, with elastic constriction for control of hemorrhage, 369
Ischemic degeneration of muscle, 793
Ischium, dislocations of hip downward on 645
Isotonic solutions, injection of, 138
Itch, 848
Itrol as antiseptic, 67
Ivy poisoning, 825

Jar, aspirating, 81
Jaundice, as factor in operation, 187
hemorrhage in, 359
Javel water, 64
in infected wounds, 247
Jaw, fractures of, 542
interdental moulded splint in, 542
lower, 543
interdental splint in, 544

Jaw, fracture of, lower, Matas' splint in, 545
plaster-of-Paris bandage in, 544
wiring in, 545
upper, 542
lower, ankylosis of, Esmarch's operation for, 726
excision of condyle for, 726
operations for, 726
dislocations of, 618
backward, 619
forward, 618
old irreducible, 619
outward, 619
upward, 619
excision of, 724
whole of, 725
fractures of, bone grafts in, 518
prosthesis for, 728
plumper for, 728
resection of, 724
alveolar process, 725
half of body, 724
and ramus, 725
segment, 726
temporary division of, 725
upper, excision of, 717
by external incision, 721
by Langenbeck's cheek-flap operation, 722
by mediolateral incision, 718
Dieffenbach's median operation for, 722
Malgaigne's operation, 722
subperiosteal, 722
operations through, to reach nasopharynx, 723
prosthesis of, 726
plumper for, 727
resection of, 717
of alveolar process, 723
of lower segment, 722
of upper segment, 723
Jaws, both upper, simultaneous excision, 722
resection of, defects after, prosthetic apparatus for, 726
Jews, susceptibility of, to disease, 18
Joani's clamp for suture of artery, 374
Joints, ankylosis of, 686
operative treatment, 686
cartilages of, dislocation of, 652
Charcot's disease of, 681
diseases of, 650
Bier's hyperemia for, 232
erasion of, 738
exposure of, 738
fractures involving, 518
hemophiliac, 682
infections of, vaccines in, 257
loose bodies in, 653
malposition of, due to contractures of soft parts, 682. See also *Malposition of joints.*
neuromimesis of, 681
neuropathic conditions of, 681
operations on, 688, 737
instruments for, 688–690
Joints, resection of, 738
spermaceti wax in, 705
stiffness of, after fractures, 525
transplantation of, 767
traumatism of, 650
tuberculosis of, 663. See also *Tuberculosis of joints.*
weak, operations to strengthen, 768
wounds of, 654. See also *Wounds of joints.*
Jute dressings, 42

Kangaroo tendon, sutures, 37
Kelen anesthesia, 117
Keloid, 225, 843
Kephalin gauze, 41
in hemorrhage, 342
Keratosis pilaris, 841
Kidney disease as factor in operation, 181
preparation of, for operation, 180
Kingsley's interdental splint, in fractures of lower jaw, 546
Knee, ankylosis of, arthroplasty for, 766
with deformity, bone grafts in, 787
arthrectomy in, 710, 752
arthrotomy of, 756
dislocations of, 647. See also *Dislocations of knee.*
erasion of, 752
excision of, 749. See also *Excision of knee.*
housemaid's, 819
intractable infections, 656
knock-, deformity in, bone grafts for, 787
opening of, 752
bisecting patella in, 753
relaxed, 686
resection of, 751
semilunar cartilage of, dislocation of, 652
sprains of, 651
stiffening of, arthrodesis in, 739
tuberculosis of, 674. See also *Tuberculosis of knee.*
Knives, 75
sharpening, 90
Knock-knee, osteotomy for, 714
Knots, tying, methods of, 190
with one hand, 203
Kocher's method of reducing hip dislocations, 644
shoulder dislocations, 627
Koch's tuberculins, 257
Kromayer's mercury inhalation treatment in syphilis, 289
Krönlein's method of dividing second and third divisions of fifth nerve in neuralgia, 876

Labarraque's solution as antiseptic, 64
Laboratory, pathologic, 167
Lacerated wounds, 219
of joints, infected, 655
Laceration of blood-vessels in fractures, 524
Lacing, plaster, 55
Lactic acid treatment of infected wounds, 241
Lamb's wool dressings, 42

Lane's bone plates, 507, 508
Langenbeck's cheek-flap operation for excision of upper jaw, 722
Laparotomy sponges, 44
Laryngeal anesthesia, 125
puncture, anesthesia by, 125
Laryngectomy, local anesthesia in, 144
Laryngitis, tuberculous, anesthesin in, 137
Larynx, operations on, local anesthesia for, 143
Lateral suture of arteries, 373
Laughing gas anesthesia, 117
Leg, amputation of, local anesthesia for, 146
nerve blocking in, 154
circumcision of, in varicose veins, 452
eczema of, 832
fractures of, in newborn, 531
gangrene of, in fractures of lower end of femur, 595
measurement of, in traction for fracture, 493
tennis, 788
Lengthening of tendons, 799
subcutaneous, 801
Lentigo, 840
Leontiasis ossium, 471
Lepra, 836
Leprosy, 836
Leukemia, 466
hemorrhage in, 360
myelogenous, 466
Leukocytosis as factor in surgical treatment, 26
effect of animal fat on, 20
Leukoderma, 843
Leverage, artificial, for reducing fractures, 476
Lichen planus, 827
ruber, 827
Ligaments, crucial, relaxed, 653
ruptured, 653
silk, in infantile paralysis with drop-foot, 802
Ligation, multiple, of varicose veins, 452
of abdominal aorta, 426
of anterior tibial artery, 443
of arteries, 401
in aneurism, 382
of head, incisions for, 404
of neck, incisions for, 404
materials for, 402
technic, 401
of axillary artery, 415
indications for, 418
of brachial artery, 418
of common carotid artery, 406
at inferior carotid triangle, 407
at superior carotid triangle, 408
indications, 408
slow, 408
iliac artery, 426
extraperitoneal, 426
of deep palmar branch of radial artery, 426
of dorsalis pedis artery, 445
of external carotid artery, 409
iliac artery, 429
Ligation of facial artery, 412
of femoral artery, 431
for varicose veins, 453
indications, 436
of gluteal artery, 430
of inferior thyroid artery, 410
of innominate artery, 403
indications, 406
of internal carotid artery, 410
iliac artery, 430
pudic artery, 431
saphenous veins for varicosity, 449
of lingual artery, 411
of occipital artery, 412
of popliteal artery, 437
of posterior auricular artery, 412
tibial artery, 441
in middle of leg, 442
of radial arteries, 421
of sciatic artery, 431
of subclavian artery, 413
of superior thyroid artery, 411
of temporal artery, 412
of ulnar artery, 424
of vertebral artery, 410
of wounded arteries, 338
Ligatures, 33
catgut, 337
in hemorrhage, 335
Lindeman's method of indirect blood transfusion, 353
Linen sutures, 38
tendons, 801
Lingual artery, ligation of, 411
nerve, division of, in neuralgia, 874
Lip, upper, carbuncle of, 253
Lipoma, 324
periosteal, 709
Lipomatosis, 324
Lipovaccines, 256
Lips, chapped, 832
eczema of, 832
protection of, in general anesthesia, 100
Liquid chlorin as antiseptic, 64
Liquor alumini acetatis as antiseptic, 68
sodæ chlorinatæ as antiseptic, 64
Liver spots, 840
Living fascia as sutures, 38
Local anemia, anesthesia by, 155
anesthesia, 127
adrenalin in, 139
advantages, 127
akoin in, 137
alypin in, 136
anesthesin in, 137
apothesin in, 137
by arterial infusion, 134
cocain in, 134
cocain adrenalin in, 135
ethyl chlorid in, 154
eucain in, 135
extraction of teeth by, 141
for abdominal section, 149
for amputations of leg, 146
for appendectomy, 150
for gastro-enterostomy, 150
for nephrectomy, 153

Local anesthesia for operations in femoral hernia, 150
in fracture of patella, 147
in umbilical hernia, 150
on abdominal wall, 148
on anus, 152
on breasts, 148
on bronchi, 144
on cervical lymphatics, 145
on ear, 143
on esophagus, 144
on extremities, 130
on female generative organs, 152
on gall-bladder, 150
on genito-urinary organs, 157
on head, 140
on inguinal hernia, 150
on lower extremities, 145
on nasal cavities, 143
on neck, 143
on palate, 143
on penis, 151, 152
on perineum, 151
on pharynx, 143
on rectum, 152
on scrotum, 152
on testes, 152
on thorax, 147
on thyroid, 144
on toes, 147
on tongue, 143
on trachea, 143
on trigeminal nerve, 143
on upper extremities, 145
on urethra, 151
on uterus, 152
on ventral hernia, 150
for removal of skin grafts, 146
for suprapubic cystotomy, 151
prostatectomy, 151
for tenotomy of tendo Achillis, 147
for thoracoplasty, 148
for thyroidectomy, 144
for tracheotomy, 143
general infiltration in, 132
holocain hydrochlorid in, 137
injection of brachial plexus in, 145
magnesium salts in, 138
methyl chlorid in, 154
nerve injection in, 131
nirvanin in, 137
normal salt solution in, 139
novocain in, 136
of mucous membrane, 127
orthoform in, 137
poisoning in, 138
preparation of patient, 129
propäsin in, 137
quinin and urea hydrochlorid in, 137
scope of, 128
stations in, 129
stovain in, 136
subcutin in, 137
technic, 129
thymol in, 137
tropocain in, 136
venous infusion in, 132
Local anesthetics, 134
Locke's solution, 58
Locomotor ataxia, salvarsan in, 294
sciatica in, 879
Loose bodies in joints, 653
Lousiness, 848
Lovett's splint in tuberculosis of hip, 671
Lower extremities, operations on, local anesthesia for, 145
Lowering of head in hemorrhage, 344
Lubricant, Irish moss, 58
Lues. See *Syphilis*.
Lumbar puncture in basal fractures of skull, 536
in spinal anesthesia, 158
vertebræ, dislocations of, 622
Lumbard's nasal tubes for ether anesthesia, 110, 111
Lungs, hypostatic congestion of, in fractures, 525
Lupus erythematosus, 841
vulgaris, 837
Luxations of tendons of quadriceps femoris muscle, 812
Lymph nodes, malignant metastases in, 466
Lymphadenitis, 461
acute, 461
chronic, 461
tubercular, 461
Lymphadenoma, malignant, 464
x-rays in, 465
Lymphangiectasis, 464
Lymphangioma, 464
Lymphangioplasty, 462
Lymphangitis, 460
Lymphatic drainage, 463
nevus, 464
obstruction, 462
operative procedures for, 462
Lymphatics, 460
cervical, operations on, local anesthesia for, 145
rupture of, 460
varicose, 464
wounds of, 460
Lymphedema, 462
in fractures, 524
Lymphoma, infective, 464
x-rays in, 465
Lymphorrhagia, 460
Lysol, 66

Macewen's osteotome, 712
Macroglossia, 464
Madura foot, 273
Magnesite dressings, 57
Magnesium hypochlorite method for infected wounds, 247
rings, absorbable, for suture of arteries, 376
salts as local anesthetic, 138
sulphate for inflammations, 234
in tetanus, 268
intraspinal injection, 161
intravenous general anesthesia with, 164
treatment of infected wounds, 248

Malar bone, fractures of, 540
Malgaigne's method for excision of upper jaw, 722
Malignant emphysema, 270
gangrene, 270
tumors. See *Cancer.*
ulcers, 315
Malleolus, fractures of, bone grafts in, 516
Malposition of joints, 682
artificial hyperemia in, 686
elastic traction in, 685
gradual manual correction, 683
operative correction, 686
rapid manual correction, 684
splints in, 684
traction by weights in, 684
Manubrium, dislocations of, 549
Marjolin's ulcer, 315
Marsden's paste in cancer, 331
Martin's bandage, for inflammation, 229
treatment of varicose ulcers, 311
Mask, chloroform, extemporized, 88
operation, 50
Massage in chronic inflammation, 249
in fractures, 500
of heart in general anesthesia, 99
suction-traction, in chronic inflammation, 250
vibratory, in neuralgia, 864
Mass-ligature in hemorrhage, 337
Matas' splint in fractures of lower jaw, 545
Mattress suture, 195
McDonald's solution as antiseptic, 70
Median nerve, injuries of, 897
Medical diseases, natural tendency of, 17
Medicated gauze, 39
Mediocarpal joint, dislocations of, backward, 638
forward, 638
Medullary fibroma of bone, 709
Members, avulsion of, 224
Membrane, Cargile, 74
Mencière's mixture as antiseptic, 70
in gas bacillus infection, 271
Mental state of patient as factor in surgical treatment, 24
Mercurial bath in syphilis, 289
Mercurialized serum in syphilis, 289, 295
Mercuric chlorid as antiseptic, 59
Mercurophen as antiseptic, 59
Mercury bichlorid as antiseptic, 59
in syphilis, 284, 285
benzoate, by injection, 289
bichlorid, 285
by bath, 289
by inunctions, 286
by mouth, 285
chlorid, injection of, 288
intravenously, 289
dosage, 285
intramuscular injections, 286
iodid, by injection, 289
methods of administration, 285
ointment, 286
oleate, 286
regulation of dose, 286
salicylate, by injection, 286
Mercury in syphilis sites for injection, 287, 288
technic for injection, 288
yellow iodid, 285
Metacarpal bones, excision of, 731
fractures of, 579
resection of, 731
joints, tuberculosis of, 680
Metallic bands in fractures, 506
bodies in wounds, microphone for removal, 224
plates in fractures, 507
Metastases, malignant, in lymph nodes, 466
Metatarsal bones, dislocations of, 649
excision of, 737
fractures of, 608
joints, tuberculosis of, 680
Metatarsophalangeal joint, first, excision of, 755
Methyl chlorid as local anesthetic, 154
ether anesthesia, 118
violet as antiseptic, 71
Methylal anesthesia, 118
Methylene bichlorid anesthesia, 118
ether anesthesia, 118
Methylene-blue in inoperable tumors, 332
Michel clamp for wounds, 187, 189
Microphone for removal of metallic bodies in wounds, 224
Milium, 845
Missing tendon, 804
Mixed-cell sarcoma of bones, 709
Moist gangrene, 317
heat method for catgut, 36
Mole, 842
Moleskin plaster, 54
Molluscum contagiosum, 837
Momburg's belt constriction in hemorrhage, 363
in postpartum hemorrhage, 365
Moore-Corradi treatment of aneurism, 382
Morestin's mixture in gas bacillus infection, 271
Moriarty's interdental splint in fractures of jaw, 546
Morison's bismuth paste in infected wounds, 248
Morphin before general anesthesia, 92
in inoperable tumors, 332
narcosis, 123
Mosetig-Moorhof's method of filling bone cavities, 705
Mosquitos, bites of, 275, 276
Mother, syphilitic, treatment during pregnancy, 301
Mother's marks, 453
Motor, electric, for bone grafting, 691
Mouse-tooth forceps, 75
Mouth gags for general anesthesia, 95
preparation of, for operation, 180
Moving unconscious patients, 184
Moynihan's cream as antiseptic, 72
Mucous membranes, local anesthesia of, 127
patches in syphilis, treatment, 302
Mucus in trachea after operation, 227
Mueller's operation in osteomyelitis, 701, 702

Murphy's incision in arthroplasty of hip, 764
Muscles, 788
actinomycosis of, 792
cicatrix of, 791
contractured, 793
contusions of, 788
degeneration, 792
ischemic, 793
gangrene of, 791
grafting of, in paralysis, 795
hernia of, 789
in hemorrhage, 342
infections of, 791
lacerated, in fractures, 524
moving forearm, 892
hand, 893
scapula and arm, 892
paralysis of, 795
rubber prosthesis in, 796
rupture of, 788
in dislocations, 612
old, 789
spasticity of, alcohol injections in, 795
syphilis of, 792
tuberculosis of, 792
tumors of, 792
wounds of, 791
Muscular spasm after fractures, 525
Musculospiral nerve, injuries to, 896
Muslin bandages, 55
protective, oiled, 54
Mycetoma, 273
Mycosis fungoides, 838
Myelogenous leukemia, 466
Myeloma, 324
Myoma, 324
Myorrhaphy, 788
Myositis, infective, 791
ossificans, 792
chronic, 792
traumatic, 792
Myxochondrosarcoma of bones, 709
Myxoma, 324
of bones, 709

Nail extension in fractures, 495
Nailing in fracture, 506
Nails, atrophy of, 848
callosity of matrix, 848
diseases of, 846
hypertrophy of, 848
infective inflammation under skin, 848
inflammation of, 848
injuries of, 847
tuberculosis about, 848
Naphthalin as antiseptic, 71
Narcosis chart, 96
morphin, 123
paralysis of brachial plexus, 895
scopolamin, 124
Narcotic agents, hypodermic, 123
Nasal boil, 273
bones, fractures of, 539
hematoma in, 539
lateral displacement in, 539
rubber tube splint in, 539
Nasal cavities, operations on, local anesthesia for, 143
septum, fractures of, 540
Nasopharynx, operations through upper jaw to reach, 723
Neck, anatomy of, 405
arteries of, ligation of, incisions for, 404
operations on, local anesthesia for, 143
prevention of shock, 215
Necrosis of bones, 468
in fractures, 525
Needles, 79
holders for, 79
method of threading, 191
Neff's clamp in aneurism, 384
Negro, susceptibility of, to disease, 18
Neosalvarsan in inoperable cancer, 332
in syphilis, by enteroclysis, 297
oil injections of, 297
Nephrectomy, local anesthesia for, 153
nerve blocking in, 153
Nerves, 850
anterior tibial, injuries, 898
auditory, injuries and diseases of, 890
blocking of, 152
alcohol injections for, 864
in amputation of leg, 154
in nephrectomy, 153
bridging of, 855
autoplastic, 855
heteroplastic, 855
cervical, injuries and diseases, 890
circumflex, injuries, 896
compression of, 851
contusions of, 851
difficulty in identifying, 850
diseases of, as factor in operation, 182
efferent, 861
external popliteal, injuries, 898
facial. See *Fifth nerve.*
grafting of, 857
in facial paralysis, 882
results, 859
hypoglossal, injuries and diseases, 893
implantation of, 857
results, 859
injections into, in local anesthesia, 131
injuries to, in dislocations, 611
in fractures, 524
intercostal, injuries, 897
median, injuries, 897
mixed, 861
musculospiral, injuries, 896
of upper extremities, injuries to, 896
operations on, 852
phrenic, injuries and diseases, 891
pneumogastric, injuries and diseases, 891
pressure on, anesthesia by, 155
recurrent laryngeal, injuries and diseases, 892
roots of, anesthetic injection of, 152. See also *Nerves, blocking of.*
sciatic, injuries, 898
spinal accessory, diseases and injuries, 890
stretching of, 860
in sciatica, 879

Nerves, suture of, primary, 853
secondary, 853, 854
time required to regain function after, 850
transplantation of, autoplastic, 856
heteroplastic, 857
homoplastic, 857
tumors of, 880
ulnar, injuries, 897
Nettle-rash, 827
Neuralgia, 862
alcohol injections in, 864
brachial, 896
causes, 863
cervico-occipital, 890
drug treatment, 863
galvanism in, 864
intercostal, 897
local hyperemia in, 864
neurectomy in, 871
of facial nerve, 877
operative treatment, 865
osmic acid injections in, 864
oxygen injections in, 865
percutaneous injections in, 864
postherpetic, 865
slow avulsion in, 871
trifacial, 865
alcohol injections in, 866
in first division, 867
in Gasserian ganglion, 869
in second division, 867
in third division, 868
results, 870
division of auriculotemporal nerve in, 874
of fifth nerve in, at entrance to bone, 873
of lingual nerve in, 874
of second and third divisions of fifth nerve in, 876
of second division of fifth nerve at foramen rotundum in, 872
of third division of fifth nerve in, 873
at base of skull in, 874
by temporary resection of zygoma, 875
vibratory massage in, 864
Neuralgic ulcers, 313
Neurectasy, 860
Neurectomy, 861
in neuralgia, 871
Neuritis, 861
acute infective, 862
irritative, 862
autotoxic, 862
chronic, 862
noninfective, 862
syphilitic, 862
toxic, 862
traumatic, 862
Neurofibroma, 324
Neurolysis, 851
Neuroma, 324
Neuromimesis of joints, 681
Neuropathic paralysis of facial nerve, 881. See also *Facial paralysis.*
Neurorrhaphy, 853. See also *Nerves, suture of.*
Neuroses of skin, 843
Neurotomy, 861
Nevus, 325
capillary, 453
lymphatic, 464
pigmentosus, 842
New growths. See *Cancer.*
Newborn, erysipelas in, 263
fractures in, 529
of clavicle, 530
of femur, 530
of forearm, 531
of humerus, 529
of leg, 531
syphilitic, treatment, 301
Nichols' operation in osteomyelitis, 695
Nirvanin in local anesthesia, 137
Nitrate of silver as antiseptic, 66
Nitric acid as caustic, 74
Nitrous oxid gas anesthesia, 117
Nitrous oxid-carbon dioxid anesthesia, 123
oxid-oxygen anesthesia, 120
No-dressing treatment of clean wounds, 210
Noma, 319
Nonabsorbable ligatures, 33
sutures, 33
Nonabsorbent drains, 47
Nonadherent dressings, 270
Nonsenile gangrene, 320
Nonunion in fractures, 529
Nose, preparation of, for operation, 180
Nosophen as antiseptic, 70
Nourishment as factor in surgical treatment, 19
in chronic inflammation, 249
Novocain as local anesthetic, 136
as spinal anesthetic, 156
Nurse, functions of, 22
gowns for, 51
instrument, 169
runabout, 169
sponge, 169
Nursing as factor in surgical treatment, 22
Nutrient injections, 20
Nutritive disturbances, 321
Nydegger's dressing in fractures of clavicle, 554

Oakum dressings, 41
Oberst tuberculin, 258
Obesity, factor of, in operation, 180
Obliterating angeitis, gangrene from, 316
Obliteration, gradual, of arteries in aneurism, 384
Obliterative operation in aneurism, 385
gradual, 384
Occipital artery, ligation of, 412
Occiput and atlas, dislocations between, 622
Occlusion of arteries, 401
treatment of fistula, 304
Occupation as factor in surgical treatment, 18
Oil injections for prevention of ankylosis, 756
of neosalvarsan in syphilis, 297

Oil of eucalyptus as antiseptic, 72
olive, surgical uses, 58
Oiled muslin protective, 54
silk protective, 53
Oil-ether rectal anesthesia, 110
after-effects, 113
after-treatment, 113
amount of anesthetic used, 113
apparatus for, 112
contraindications, 113
ingredients for, proportions, 114
technic, 112
Olecranon, fractures of, 572
bone grafts in, 511
fibrous union in, 573
Olive oil, surgical uses, 58
Ollier's operation through upper jaw to reach nasopharynx, 724
Onychauxis, 848
Onychia, 848
maligna, 848
Onychitis, 848
Onychomycosis, 848
Open operation for reduction of dislocation of hip, 616
tenotomy, 813
treatment of infected wounds, 240
Open-drop method for ether anesthesia, 107
Operating, best time for, 184
caps, 50
clothes, surgeon's, 51, 173
masks, 50
personnel, arrangement of, 169
room, 166
for special operations, 167
table, 85
extemporized, 87, 88
positions secured on, 86
Operations, 17, 184
arrangement of instruments at, 169
collapse during, 218
dangers of, 184
for ankylosis, 757
for coxa valga, 770
vara, 770
in private houses, 169
in tent, 169
jackets for patient during, 49
on bones and joints, 688
instruments for, 688–690
on joints, 737
on nerves, 852
preparation of patient, 176. See also *Patient, preparation of.*
prevention of pain after, 214
self-performed, 224
stockings for patient, 48
suit for patient, 94
time consumed in, 184
to compensate loss of epiphysis, 769
to lengthen bones, 770
to strengthen weak joints, 768
treatment after, 225
without anesthetics, 165
Operative field, preparation of, 177
acetone-pyxol for, 178
aseptic mechanical method, 178
Operative field, iodin for, 178
picric acid method, 178
wounds, 184
technic of making, 184
Opsonins, 26
Optic nerve, syphilis of, 297
Orbit, punctured fractures of skull through, 537
Organic silver salts as antiseptic, 66
tissues, filling bone cavities with, 704
Oriental boil, 273
sore, 273, 314
Orthoform in local anesthesia, 137
Os calcis, fractures of, 608
bone grafts in, 517
Osmic acid injections in neuralgia, 864
Osteitis, 467
deformans, 471
operations for, 692
typhoid, 469
Osteo-arthritis, arthrodesis in, 739
Osteogenesis imperfecta, 471
Osteoma, 324, 470
Osteomalacia, 471
Osteomyelitis, acute, 469
autoplastic operations with bone in, 698
with soft tissue in, 697
chronic, operation in, 696
early operation for, 693
filling defects in, with autoplastic bone flaps, 699
operations for, 692
for loss of substance in, 699
stages of, 694
subacute, operation in, 695
vaccines in, 257
Osteoplastic excision of elbow-joint, 745
operations, 710
for cranial defects, 711
periostitis, chronic, 467
resection of anterior portion of palate, 723
of hard palate, 723
Osteoplastic-flap operations through upper jaw to reach nasopharynx, 724
Osteosarcoma of head and neck of humerus, 706
periosteal, 709
Osteotome, Macewen's, 712
Osteotomy combined with resection of long bones, 716
cuneiform, 713
for genu valgum, 714
of femur, 713
in knee tuberculosis, 677
supracondyloid, from inner side, 715
from outer side, 715
of long bones, 711
technic, 712
of lower end of femur, 714
of neck of femur, 713
in old unreduced hip dislocations, 647
of shaft of tibia, 716
subtrochanteric, 714
of tibia, 716
below tuberosities, 716
of upper end of femur, 713

Overfeeding, dangers of, 20
Oxalic acid as antiseptic, 67
Oxidation, sterilization by, 30
Oxygen, anesthetics combined with, 120
gas for treatment of shock, 216
injections in neuralgia, 865
interstitial injections of, 358
intravenous injections of, 357
Oxymethylene as antiseptic, 68

Pads, rubber, 53
Pain areas, sensory, 128
in fractures, 525
in scars, 225
postoperative, 226
prevention of, after operations, 214
Palate, anterior portion, osteoplastic resection of, 723
hard, osteoplastic resection of, 723
operations on, local anesthesia for, 143
Palmar branch, deep, of radial artery, ligation of, 426
Palsy. See *Paralysis.*
Bell's. See *Facial paralysis.*
Paper wool dressings, 42
Papilloma, 324
Paquelin cautery, 80
Paraffin method for catgut, 36
occlusion treatment of burns, 823
Paraffined gauze, 41
linen sutures, 38
paper protective, 54
silk sutures, 38
Paraform as antiseptic, 68
Paraformaldehyd as antiseptic, 68
Paralysis, brachial birth, 894
crutch, in fractures, 527
facial, 881. See also *Facial paralysis.*
grafting muscles in, 795
in fractures, 525
infantile, arthrodesis in, 738
with drop-foot, silk ligaments in, 802
narcosis, of brachial plexus, 895
of biceps of arm, tendon transplantation in, 812
of deltoid muscle, 795
of extensors of hand, tendon transplantation in, 812
of facial nerve, neuropathic, 881. See also *Facial paralysis.*
of muscles, rubber prosthesis in, 796
of quadriceps extensor of thigh, tendon transplantation in, 812
of trapezius muscle, 795
traumatic, in general anesthesia, 100
Paralytic dislocation of hip-joint, bone grafts in, 783
of shoulder, 634
scoliosis, bone grafts in, 782
talipes calcaneus, tendon transplantation in, 812
equinus, tendon transplantation in, 812
valgus, tendon transplantation in, 811
varus, tendon transplantation in, 812
Parasacral anesthesia, 162
Parasites, animal, of skin, 848
Paravertebral anesthesia, 152
Parents, syphilitic, prophylactic treatment before conception, 301
Paresis, general, salvarsan in, 294
salvarsan in, intraventricular injection, 296
Paronychia, 848
Passive motion in chronic inflammation, 249
Paste, adhesive, 55
Pasteur treatment of hydrophobia, 273
Patella, ankylosis of, arthroplasty for, 767
bisecting of, in opening knee-joint, 753
dislocations of, 648
congenital, 618
habitual, bone grafts in, 787
excision of, 732
fractures of, 596. See also *Fractures of patella.*
pad, inflamed, 653
strengthening of, 733
Patient, care of, as factor after operation, 26
during operation, 182
in general anesthesia, 101
color of, in general anesthesia, 99
mental state of, as factor in surgical treatment, 24
operation suit for, 94
preparation of, for anesthesia, 92
for local anesthesia, 129
for operation, 176
for special operations, 180
in emergency, 180
unconscious, moving of, 184
Peat dressings, 42
Pediculosis, 848
Pediculus capitis, 848
corporis, 848
pubis, 848
Pegging fragments in fractures, 506
Pelvic aneurism, 398
veins, excision of, in septic thrombophlebitis, 456
Pelvis, bones of, resection of, 732
fractures of, 582
Pemphigus, 830
Penhallow's splint in fractures of shaft of humerus, 561
Pen-holder hold of operating scalpel, 185
Penis, operations on, local anesthesia in, 151, 152
preparation for, 180
Pendjeh sore, 273
Pental anesthesia, 118
Percutaneous injections in neuralgia, 864
Perhydrol as antiseptic, 68
Perineal protectors, 48
Perineum, operations on, local anesthesia in, 151
preparation for, 180
Perionychia, 848
Periosteal fibroma, 709
lipoma, 709
osteosarcoma, 709
Periosteum, elevation of, 688
interposition of, for ankylosis, 759
Periostitis, 467
acute, 467

Periostitis, chronic, 467
osteoplastic, 467
operations for, 692
Peripheral injections in inoperable cancer, 333
Perithelioma of bones, 710
Perléche, 829
Permanganate of potash as antiseptic, 67
method of hand sterilization, 174
Pernicious anemia in hemorrhage, 360
Pernio, 319, 826
Peroneus longus, transplantation of, for tibialis anticus, 810
tertius, transplantation of tibialis anticus for, 810
Peroxid of hydrogen as antiseptic, 68
Peroxid-phenol, hot, in infected wounds, 247
Perspiration, abnormal odor of, 844
diminished, 844
excessive, 844
of hands, treatment, 849
Phagedenic gangrene, 319
ulcers, 313
Phagocytosis as factor, 26
Phalangeal joints, tuberculosis of, 680
Phalanges, bone grafts of, 786
dislocations of, 649
excision of, 731
fractures of, 580, 608
proximal, of fingers, dislocations of, 639
resection of, 731
Phalanx, proximal, of thumb, dislocation of, 639
Pharyngeal insufflation in ether anesthesia, 110
Pharynx, anesthesia by, 124
operations on, by local anesthesia, 143
Phenol, 65
gangrene, 320
gauze, 40
halogen derivatives, 60
in tetanus, 268
liquefied, in soiled wounds, 186
Phenol-camphor treatment for boils, 253
of infected cavities, 234
Phenolized glycerin as antiseptic, 66
Phlebitis, 447
acute, 447
non-infective, 447
Phlebotomy, 453
Phlegmonous erysipelas, 262
Phosphorus necrosis of bones, 468
Phrenic nerve, injuries and diseases of, 891
Picric acid as antiseptic, 67
for preparation of operative field, 178
in burns, 821
Pillow extension in fractures, 493
Pimples, 835
Pin sutures, 197
Pituitary extract for treatment of shock, 217
Pityriasis rosea, 836
Plasma marina in septicemia of unknown origin, 261
Plaster lacing, 55
moleskin, 54
protective, adhesive, 54
Plaster, resin, 35
Plaster-of-Paris bandages, 37
in fracture of lower jaw, 544
case in fractures of shaft of femur, 591
splints, 477
bisected case, 481
fenestra in, 481
gutter, 483
in tuberculosis of hip, 668
method of application, 477
of cutting, 481
of making, 478
traction after application, 479
Plastic ankylosing arthritis, 662
Plates, lateral, for suture of arteries, 376
metallic, in fractures, 507, 508
Plexus, brachial, 892. See also *Brachial plexus*.
Plication of arteries in aneurism, 384
Plumper for prosthesis in upper jaw, 727
of lower jaw, 728
Pneumatic extension in fractures, 494
suit, Crile's, for prevention of shock, 216
Pneumococcus arthritis, 660
Pneumogastric nerve, injuries and diseases of, 891
Pneumonia, aspiration, from ether, 105
postoperative, prevention of, 180
Poisoning, ergot, gangrene from, 318
from local anesthetics, 138
ivy, 825
primrose, 826
ptomain, 259
skin, 825
sumac, 825
Poisons, gangrene from, 320
Polymerized formaldehyd as antiseptic, 68
Polymyositis, acute, 791
Popliteal aneurism, 399
artery, compression of, for hemorrhage, 367
ligation of, 437
blood-vessels, injury of, in fractures of lower end of femur, 595
nerve, external, injuries of, 898
space, anatomy of, 437
Port wine stains, 453
Portal vein, thrombosis of, 457
vena cava and, anastomosis between, 458
Positions for general anesthesia, 94
secured on operating table, 86
Postfebrile gangrene, 320
Postherpetic neuralgia, 865
Postoperative hemorrhage, prevention, 181
pneumonia, prevention of, 180
tetanus, 270
treatment, 225
Postpartum hemorrhage, Momburg's constriction belt in, 365
Post's anesthetic mixture, 119
Potassium bitartrate for suppurating wounds, 212
hydrate as caustic, 73
hypochlorite as antiseptic, 64
treatment of infected wounds, 247
iodid in syphilis, 290

Potassium mercuric iodid method for catgut, 35
permanganate as antiseptic, 67
Pott's fracture, 606
Poultice for inflammations, 234
in wound infection, 28
Poupart's ligament, ligation of femoral artery below, 435
Pregnancy as factor in operation, 182
treatment of mother in, for syphilis, 301
Preparation of patient, 176. See also *Patient, preparation of.*
Presenile gangrene, 320
Pressure as hemostatic, 334
for chronic inflammation, 250
ulcers, 313
Primrose poisoning, 826
Private houses, operations in, 169
Probes, 75
Proctoclysis, 344
Propäsin in local anesthesia, 137
Prostate, diseases of, as factor in operation, 182
preparation of, for operation, 180
Prostatectomy, suprapubic, local anesthesia in, 151
Prosthesis for defects after resection of jaws, 726
for lower jaw, 728
plumper for, 728
of upper jaw, 726
plumper for, 727
rubber, in paralysis of muscles, 796
Prostration as contraindication to operation, 180
Protargol as antiseptic, 67
Protective inoculations, 255
materials, impervious, 52
Protectors, 48
perineal, 48
Proteid, injections of, 21
Prurigo, 836
Pruritus, 843
of anus, 843
of genitals, 843
Pseudoleukemia, 464
x-rays in, 465
Psoas parvus muscle, contracture of, simulating appendicitis, 796
Psoriasis, 833
chrysarobin-serum treatment, 835
local treatment, 834
of tongue, 834
vaccines in, 835
Psychic treatment of shock, 216
Ptomain poisoning, 259
Pudic artery, internal, ligation of, 431
blocking of, 153
Puerperal septicemia, vaccine and serum therapy in, 257
Pulmonary artery, embolism of, 457
diseases as factor in operation, 182
hyperemia, postoperative, 227
Pulse in general anesthesia, 98
Puncture, laryngeal, anesthesia by, 125
venous, 453
Punctured wounds, 219
Punctured wounds of joints, 654
Purpura, hemorrhage in, 360
Purse-string suture, 201
Pus inoculations in suppuration, 258
Putrefactive organisms, wound infection with, 212
Pyemia, 260
Pyocyaneus infection, 261
Pyoktanin as antiseptic, 71
in inoperable cancer, 332
Pyxol as antiseptic, 70

Quadriceps extensor of thigh, paralysis of, tendon transplantation in, 812
femoris muscle, tendons of, luxations of, 812
Quinin and urea hydrochlorid as local anesthetic, 137
hydrochlorid as antiseptic, 71

Race as factor in surgical treatment, 17
Radial artery, ligation of, 421
of deep palmar branch, 426
Radium in inoperable cancer, 333
Radius, dislocations of, backward, 637
congenital, 618
forward, 637
old, 638
outward, 637
excision of, 731
fractures of, 572
head, 572
lower end, 575. See also *Fractures, Colles'.*
neck, 572
shaft, 573
resection of, 731
subluxations of head, by traction, 637
Raynaud's gangrene, 318
Reactionary hemorrhage, 358
Rebreathing in anesthesia, 123
Receptaculum chyli, wounds of, 460
Reconstructive operation in aneurism, 389
Recovery room, 167
Rectal anesthesia, ether vapor, 114
oil-ether, 110. See also *Oil-ether rectal anesthesia.*
Rectum, operations on, local anesthesia in, 152
Recurrent dislocations, 612
laryngeal nerve, injuries and diseases of 892
Regional anesthesia, 127
Reindeer tendon sutures, 37
Relaxed crucial ligament, 653
knee-joint, 686
Resection of alveolar process of lower jaw 725
of upper jaw, 723
of bones, 717
of pelvis, 732
of calcaneum, 734
of clavicle, 729
of femur, 732
of fibula, 734
of half of body and ramus of lower jaw, 725
of lower jaw, 724

Resection of head of scapula, 730
of humerus, 730
of jaws, defects after, prosthetic apparatus for, 726
of joints, 738
of knee-joint, 751
of lower jaw, 724
segment of upper jaw, 722
of metacarpal bones, 731
of phalanges, 731
of radius, 731
of scapula, 730
of segment of lower jaw, 726
of tibia, 733
of ulna, 731
of upper jaw, 717
segment of upper jaw, 723
of zygoma for exposure of temporomaxillary joint, 740
osteoplastic, of anterior portion of palate, 723
of hard palate, 723
Resin plaster, 54
Resistance to disease as factor in surgical treatment, 19, 26
Respiration, artificial, in general anesthesia, 98
in general anesthesia, 97
Rest treatment for infected wounds, 187
in tuberculosis, 279
of acute inflammation, 229
of chronic inflammation, 250
Resterilization of supplies, 51
Restorative operation in aneurism, 389
Restraint in general anesthesia, 101
Retention of urine, postoperative, 226
Retractors, 77, 78
extemporized, 87
Rheumatic arthritis, 660
fever, 660
synovitis, 660
Rheumatism, 658, 660
articular acute, 660
Rheumatoid arthritis, 661
Ribs, dislocation of, 623
fractures of, 549
Rickets, 321
Rider's thigh, 788
Ringer's solution, 58
Ringworm, 839
of scalp, 839, 840
vaccines in, 840
Rivallié's caustic, 74
Rodent ulcer, 315
Roentgen rays. See *X-rays*.
Rolled splints, 477
Rollier treatment of tuberculosis, 280
Rotary dislocations of knee, 648
of patella, 648
Round-cell sarcoma, small, of bones, 709
Rubber bandages, 56
cushions, 22, 23
dam, 53
drainage tubes, 45
finger cots, 53
gloves, care of, 174
method of adjusting, 174
Rubber gloves, sterilization of, 52. See also *Sterilization*.
pads, 53
prosthesis in paralysis of muscles, 796
protective for open wounds, 209
sheeting, 53
tissue, 53
Rubefacients for inflammations, 234
Rückstand tuberculin, 257
Runabout nurse, 169
Rupture. See *Hernia*.
of crucial ligaments, 653
of lymphatic vessels, 460
of tendons, 797
Rydygier's method in old unreduced hip dislocations, 647

Sacral epidural injections for anesthesia, 162
Sacro-iliac joint, 651
bone grafts in, 783
sprains of, 651
tuberculosis of, 680
Sagittal sinus, intravenous infusion into, in infants, 347
Salicylic acid as antiseptic, 67
Saline infusion, 346
gum acacia in, 348
in sagittal sinus in infants, 347
intracellular, 346
intravenous, 346
pack, for infected wounds, 241
solutions, 58
chlorinated, 63
for filling bone cavities, 705
normal, as local anesthetic, 139
injections of, in sciatica, 878
Salts, organic silver, as antiseptic, 66
Salvarsan in general paresis, 294
in inoperable cancer, 332
in locomotor ataxia, 294
in paresis, intraventricular injection, 296
in syphilis, 291
apparatus for injection, 292, 293
arsenical poisoning from, 293
by enteroclysis, 297
by mouth, 297
contraindications, 292
dosage, 293
intramuscular injections, 297
intraspinal method, 294
intraventricular injection, 296
preparation of solution, 291
subcutaneous injection, 297
subdural intracranial injections, 296
in yaws, 303
technic of injection, 292
Salvarsanized serum in syphilis, 295
Sand bags, 82
treatment of varicose ulcers, 311
Sand-fleas, bites of, 276
Saphenous vein, internal, ligation of, in varicose veins, 449
Sarcoma, bone, 470
mixed-cell, 709
small round-cell, 709
spindle-cell, 709

Sarcoma, giant-cell, of long bones, 707, 709
of tibia, 706
of ulna, 707
Sartorius, tendons of, tenotomy of, 815
Sawdust dressings, 42
Sayre's dressing, modified, in fractures of clavicle, 552
Scabies, 848
Scaffold splint in fracture of shaft of humerus, 564
Scalp, eczema of, 83
preparation of, for operation, 180
ringworm of, 839
vaccines in, 840
seborrhea of, 844
Scalpel, methods of holding, 184
pen-holder hold of, 185
table knife hold of, 185
violin hold of, 184
Scapula, excision of, 730
fractures of, 556. See also *Fractures of scapula.*
muscles moving, 892
resection of, 730
head of, 730
Scarification of ulcers, 310
Scarlatina, surgical, 261
Scarpa's triangle, lower part, ligation of femoral artery at, 435
Scars, 225
adherent, 225
painful, 225
Schäfer's method of artificial respiration in general anesthesia, 98
Schiassi's serum, 58
Schichhold method of reducing shoulder dislocations, 628
Schleich's solutions, 119
for local anesthesia, 135
Schroeder's apparatus for moving bones in fractures, 497
Sciatic artery, ligation of, 431
nerve, injuries of, 898
Sciatica, 878
air injections in, 879
in locomotor ataxia, 879
injections of normal salt solution in, 878
nerve stretching in, 879
Sclavo's serum in anthrax, 272
Scleroderma, 843
Scoliosis, paralytic, bone grafts in, 782
Scopolamin narcosis, 124
Scorbutic ulcers, 314
Scorpion, bites of, 276
Screws in fractures, 507
Scrotum, eczema of, 832
elephantiasis of, 464
operations on, local anesthesia in, 152
Scrubbing hands, 173. See also *Sterilization of hands.*
Scurvy, 321
hemorrhage in, 360
Sea sponges, 42
water for inflammations, 234
in septicemia of unknown origin, 261
Sebaceous cyst, 845
Seborrhea, 844
Seborrhea of scalp, 844
oleosa, 845
Secondary hemorrhage, 358
Self-performed operations, 224
Semilunar cartilage of knee-joint, 652
Semimembranosus, tendons of, tenotomy of, 815
Semitendinosus, tendons of, tenotomy of, 815
Senile gangrene, 317
osteomalacia, 471
Sensory pain areas, 128
Septic infections, acute, as factor in operation, 182
Septicemia, 259
antitoxins in, 260
bacteria causing, 259
blood transfusion in, 260
following wounds and abscesses, vaccines in, 257
of unknown origin, 261
intravenous injection of antiseptics in, 261
sea water in, 261
prophylaxis, 259
puerperal, vaccine and serum therapy in, 257
serum therapy in, 256
treatment, 260
vaccines in, 256, 260
Septum, nasal, fractures of, 540
Sequences, anesthetic, 118
Sequestration of blood for control of hemorrhage, 369
Serum, 255
beef, 59
Calmette's, in snake bite, 275
mercurialized, in syphilis, 295
salvarsanized, in syphilis, 295
Schiassi's, 58
treatment, 255
in anthrax, 272
in inoperable cancer, 332
in puerperal septicemia, 257
in septicemia, 256
in tuberculosis, 279
Sesamoid bone of thumb, fracture of, 582
Seton in chronic inflammation, 250
Sex as factor in surgical treatment, 18
Sharpening knives, 90
Shell wounds, 222
Sheets, 48
abdominal, 48
rubber, 53
Shingles, 830
Shock, 213, 217
acidosis in, 213
as contraindication to operation, 180
as factor in surgical treatment, 25
local protection against, 215
prevention of, 214
susceptibility of children to, 19
treatment of, 215
Shoemaker's suture, 198
Shortening tendons, 804
Shoulder, ankylosis of, arthroplasty for, 761

Shoulder, dislocations of, 626. See also *Dislocations of shoulder.*
excision of, 741. See also *Excision of shoulder.*
sprains of, 652
tuberculosis of, 679
Shrapnel wounds, 222
Sick-room dainties, fallacy of, 20
Silicate of soda splints, 485
Silk ligaments in infantile paralysis with drop-foot, 802
oiled, protective, 53
paraffined, for sutures, 38
tendons, 801
thread sutures, 38
Silver albuminate as antiseptic, 67
citrate as antiseptic, 67
colloidal, as antiseptic, 67
foil protective, 54
ichthyol as antiseptic, 67
lactate as antiseptic, 67
nitrate as antiseptic, 66
as caustic, 73
salts, organic, as antiseptic, 66
stains, removal of, 67
wire sutures, 38
Silver-fork deformity in Colles' fracture, 575
Silvol as antiseptic, 67
Sinclair's adhesive paste, 55
Sinus, sagittal, intravenous infusion into, in children, 347
Sinuses, 304, 305
bismuth paste injections in, 306
Skillern's treatment of varicose ulcers, 311
Skin, 820
animal parasites of, 848
burns of, 820. See also *Burns of skin.*
condition of, in fractures, 476
contusions of, 820
cosmetics, 849
diseases, atrophic, 843
autoserum treatment, 849
hypertrophic, 840
of glands, 844
dry, 844
cold cream for, 849
excessive sweating of, 844
grafts, removal of, local anesthesia for, 146
hard, 841
infections, 825
inflammations, 825
irritation in chronic inflammation, 250
neuroses of, 843
new growths of, 843
poisoning, 825
removal of tattoo marks, 849
traumatism of, 820
tuberculosis of, 837
white, 843
wire traction from, in fracture, 493
wounds of, 820
Skull, arteries of, ligation of, incisions for, 404
bone grafts of, 775
for defects 775
operation for covering, 700
osteoplastic operations for, 711
Skull, fractures of, 532. See also *Fractures of skull.*
operations on, local anesthesia for, 140
prevention of shock, 215
Sleep, twilight, 124
Sliding bone grafts, 509
splint of Volkmann, 491
Slings, 49
Sloughing gangrene, 319
ulcers, 314
wounds, 221
Snake bite, 274
treatment, 275
Snare, 79
Soap, alcoholic, as antiseptic, 72
treatment of infected wounds, 248
Sodium borate as antiseptic, 67
citrate method of indirect blood transfusion, 356
dimethylarsenate in syphilis, 298
hypochlorite as antiseptic, 61, 64
in infected wounds, 242, 247
oxymercury-orthonitro-phenolate, 59
persulphate in tetanus, 268
succinate in infections, 258
Soiled wounds, treatment, 186
Solidified alcohol as antiseptic, 72
Solutions, 57, 58
acid bichlorid as antiseptic, 59
boro-salicylic as antiseptic, 68
gutta-percha, 53
hypertonic, injection of, 138
hypochlorite, method for, 62
hypotonic, injection of, 138
isotonic, injection of, 138
Labarraque's, as antiseptic, 64
Locke's, 58
McDonald's, as antiseptic, 70
Ringer's, 58
saline, chlorinated, 63
Schiassi's, 58
table of, 60
Thiersch's, 41
as antiseptic, 68
Woelfler's, 73
Wright's, 58
Solveol as antiseptic, 66
Somnoform anesthesia, 118
Sore, Oriental, 273, 314
Pendjeh, 273
Soresi's blood transfusion apparatus, 352
Spasm of facial muscles, 888
tetanic, 264
Specific arthritis, acute, 660
synovitis, acute, 660
Spermaceti wax for filling bone cavities, 705
in resection of joints, 705
Sphagnum cymbifolium, 42
Spiders, bites of, 276
Spina bifida, bone grafts in, 783
Spinal accessory nerve, diseases and injuries of, 890
grafting of, in facial paralysis, 882
anesthesia, 155
cerebrospinal fluid in, 156
cocain in, 156
high, 161

Spinal anesthesia in sciatica, 879
lumbar puncture in, 158
novocain in, 156
stovain in, 156
technic, 157
tropocain in, 156
injection of antitetanic serum, 266
Spindle-cell sarcoma of bones, 709
Spine, bone grafts of, 776. See also *Bone grafts of spine.*
irritable, 681
Spiral circumcision of leg for varicose veins, 453
Splints, ambulatory, 522
double armed, for fractures of clavicle, 530
lateral, in fractures of shaft of femur, 592
right angle, for fractures of humerus, 529
Dupuytren, in Pott's fracture, 606
emergency, 472
extemporized, 474
Goldthwait's thumb, 582
hip, in fractures of shaft of femur, 591
Hodgen's, in impacted fracture of neck of femur, 585
in malposition of joints, 684
interdental, in fractures of lower jaw, 542, 544, 546
moulded, in fractures of jaw, 542
Lovett's, in tuberculosis of hip, 671
Matas', for fractures of lower jaw, 545
materials for, 477
Penhallow's, in fractures of shaft of humerus, 561
plaster-of-Paris, 477. See also *Plaster-of-Paris splints.*
rolled, 477
rubber tube, in nasal fractures, 539
scaffold, in fracture of shaft of humerus, 564
side, for fracture of femur, 492
silicate of soda, 485
sliding, of Volkmann, 491
starch paste, 485
suspension, bed frame for supporting, 488
in fractures of shaft of femur, 591
Thomas', in impacted fracture of neck of femur, 585
knee-, in tuberculosis of knee-joint, 675
traction, in tuberculosis of hip, 669
wire frame suspension, 487
Split retractors, 49
Spondylitis, tuberculous, bone grafts in, 776. See also *Bone grafts of spine.*
Spondylolisthesis, bone grafts in, 783
Sponges, 42
abdominal, 44
counting of, 172
flat, 44
gauze, 43
hand, 43
holders for, 79
laparotomy, 44
nurse in charge of, 169
sea, 42
stick, 44
Spongy angioma, 454
Spontaneous cure in cancer. 331
dislocations, 613
gangrene, 320
subluxations of wrist, 638
Sporotrichosis, 838
Spots, liver, 840
Sprains, 650
of ankle, 650
of hip, 652
of knee, 651
of sacro-iliac joint, 651
of shoulder, 652
of temporomaxillary joint, 651
of vertebræ, 651
of wrist, 652
old, 650
Spring-eyed needles, 79
Stab wounds, 219
Stains, port wine, 453
silver, removal of, 67
Staphylococci, infection of wounds with, 212
Starch bandages, 56
iodized, for infected wounds, 242
paste splints, 485
Starvation treatment of inoperable cancer, 333
Stations in local anesthesia, 129
Status lymphaticus as factor in operation, 181
general anesthesia in, 102
Steam, live, as hemostatic, 339
sterilizer, 29
therapeutic uses, 57
Steatoma, 845
Sterile water, 57
anesthesia, 139
preparation of, 32
Sterilization, 28
by boiling water, 31
by chemicals, 30
by dehydration, 30
by heat, 28
by oxidation, 30
by sun's rays, 30
fractional, 28
of catgut, 34. See also *Catgut, sterilization of.*
of dressings, 31
of forearms, 173
of hands, 173
acetone-pyxol method, 174
cresol-acetone method, 174
permanganate of potash method, 174
tannin method, 174
tincture of iodin method, 174
of instruments, 89
of rubber gloves, 52
dry air method, 52
glycerin method, 52
sulphuric acid method, 52
of surgical materials, 33
Sterilizer, combination, 31
hot-water, 29
steam, 29
Sterilizing room, 167

Sternomastoid muscle, tendons of, tenotomy of, 815
Sternum, fracture of, 548
Stick sponges, 44
Stimson's method of reducing hip dislocations, 641, 644
shoulder dislocations, 629
Stimulation in general anesthesia, 98
Stimulants in general anesthesia, dangers of, 98
Stings of insects, 275
Stock vaccines, 256
Stockings, operation, 48
Stomach, preparation of, for operation, 180
Stomatitis, gangrenous, 319
Store room, 167
Stovain as local anesthetic, 136
as spinal anesthetic, 156
Straps, adhesive, for wounds, 187, 188
Streptococcus infection, 262
Stretching of nerves, 860
Styptics in hemorrhage, 341
Subacromial dislocation of clavicle, 625
Subcervical fractures of great trochanter of femur, 583
Subclavian aneurism, 400
artery, anatomy of, 414
compression of, in hemorrhage, 360
ligation of, 413
Subcoracoid dislocation of clavicle, 625
Subcutaneous injection of magnesium sulphate in tetanus, 269
of proteids, 21
of salvarsan in syphilis, 297
lengthening of tendons, 801
nutrient injections, 20
tenotomy, 813
Subcuticular suture, 192
Subcutin as local anesthetic, 137
Subdural intracranial injections of salvarsan in syphilis, 296
Subglenoid dislocation of shoulder, 630
Sublamin in syphilis, 295
Subluxations of head of radius by traction, 637
of vertebræ, 623
of wrist, spontaneous, 638
Subperiosteal excision of upper jaw, 722
Subtrochanteric osteotomy, 714
Subungual hematoma, 847
Suction-traction massage in chronic inflammation, 250
Sugar infusion, 348
Suggestion, anesthesia by, 127
Sulphuric acid as antiseptic, 72
method of sterilization of rubber gloves, 52
Sumac poisoning, 825
Sunburn, 825
Sunshine in tuberculosis, 279
sterilization by, 30
Superfluous hair, 846
Suppurating wounds, hot-air treatment, 187
potassium bitartrate for, 212
Suppuration, acute, 251. See also *Abscess.*
Supracervical fractures of great trochanter of femur, 583
Supracondyloid fractures of femur, 594
of humerus, 567
low, 571
osteotomy of femur from inner side, 715
from outer side, 715
Suprarenal capsules, effect of chloroform on, 117
Surface contact anesthesia, 127
Surgeon, mental attitude of, as factor in surgical treatment, 25
operating clothes of, 173
personal care, 172
private room of, 167
room of, 167
Surgical accessories, 48
anemia, 343
diseases, 17
expedients, 87
fevers, aseptic, 259
instruments, 75
materials, preparation of, 33
sterilization of, 33
scarlatina, 261
shock, 213. See also *Shock.*
Suspension splints, bed frame for supporting, 488
wire frame, 487
Sutures, 33, 187
absorbable, 33
approximation, 196
bolster, 197
buried, 191
button, 197
chain, 195
tied, 200
coaptation, 196
continuous, 190
figure-of-eight, 198
double, 198
infolding, 201
interlocking, 201
interrupted, 187
mattress, 195
non-absorbable, 33
of arteries, 374
absorbable magnesium rings for, 376
human hair for, 372
invagination method, 376
Joani's clamp for, 374
lateral, 373
plates for, 376
temporary compression for, 372
of bones in fractures, 503
of nerves, primary, 853
secondary, 853, 854
time required to regain function after, 850
pin, 197
purse-string, 201
removal of, 211
shoemakers', 198
strengthening of, by autoplastic flaps, 203
subcuticular, 192
tension, adhesive support for, 198
Sweating, excessive, of hands, 849
of skin, 844

Sycosis, 847
Sylvester's method of artificial respiration in general anesthesia, 98
Sympathetic ganglia, cervical, 898. See also *Cervical sympathetic ganglia.*
Synovectomy, 710
in infections, of knee-joint, 656
in knee-joint, 710
Synovitis, 657
atrophic, 658
chronic, 658, 661
exudative, 658
infective, acute, 658
rheumatic, 660
specific, acute, 660
traumatic, 657
Syphilis, 283
alopecia in, treatment, 303
arsenobenzol in, 298
arsphenamin in, 298
as factor in operation, 182
calomel injections in, 288
chancre, treatment, 302
colloidal gold test in, 299
diagnosis, 283
drugs in, 284
dry skin lesions in, treatment, 302
excision of chancre, 284
gummatous ulcerations in, treatment, 302
hereditary, 301
herpes progenitalis in, treatment, 302
hydrargyrism in, 289
hydrotherapy in, 298
hygiene in, 284
intensive treatment, 299
iodin in, 290
iodism in, 291
iritis in, treatment, 302
lesions of, local treatment, 302
mercurialized serum in, 289, 295
mercury in, 284, 285. See also *Mercury in syphilis.*
mercury-iodid in, 291
mistakes in treatment, 299
mucous patches in, treatment, 302
neosalvarsan in, 294
by enteroclysis, 297
oil injections of, 297
of bones, 470
of joints, 680
of muscle, 792
of optic nerve, 297
opalescent patches in, treatment, 302
potassium iodid in, 290
prevention, 283
primary stage, 300
salvarsan in, 291. See also *Salvarsan in syphilis.*
salvarsanized serum in, 295
secondary stage, 300
self-healing of, 299
sluggish ulcers in, treatment, 302
sodium dimethylarsenate in, 298
sublamin in, 295
tertiary stage, 300
treatment of mother during pregnancy in, 301
Syphilis, treatment of newborn in, 301
prophylactic, of parents before conception, 301
Treponema pallidum in, 283
vegetations in, treatment, 302
Wassermann test in, 299
Syphilitic neuritis, 862
tenosynovitis, 817
Syphiloderma, 838
Syringes, 79
aspirating, 81

Tabetic arthropathy, 681
Table, instrument, 169
operating, 85
Table-knife hold of operating scalpel, 185
Talipes calcaneus, paralytic, tendon transplantation in, 812
equinus, paralytic, tendon transplantation in, 812
valgus, paralytic, tendon transplantation in, 811
varus, paralytic, tendon transplantation in, 812
Tanner's ulcer, 315
Tannic acid method for catgut, 37
Tannin method of hand sterilization, 174
Tarantula, bites of, 276
Tarsus, dislocations of, 649
excision of, 734
fractures of, 608
Tattoo marks, removal of, from skin, 849
T-bandage, 49
Teeth, extraction of, by local anesthesia, 141
Temporal artery, ligation of, 412
Temporomaxillary joint, ankylosis of, arthroplasty for, 760
exposure of, by resection of zygoma, 740
sprain of, 651
Tendo Achillis, tenotomy of, local anesthesia in, 147
Tendons, 796
grafting, 805
lengthening of, 799
subcutaneous, 801
linen, 801
missing, 804
of quadriceps femoris muscle, luxations of, 812
reconstruction of, with fascia, 803
with transplanted vein, 803
repair of, 796
rupture of, 797
shortening, 804
silk, 801
suturing to bone, 804
transplantation of, 805. See also *Transplantation of tendons.*
wounds of, 796
old, 816
Tennis leg, 788
Tenorrhaphy, 796
Tenosynovitis, 817
gonorrheal, 817
infective, 817

Tenosynovitis, syphilitic, 817
toxemic, 817
traumatic, 817
tuberculous, 817
Tenotomy, 813
healing in, 814
of biceps femoris tendon, 815
of flexor hallucis longus tendon, 815
of gracilis tendon, 815
of hamstring tendons, 815
of peronei tendons, 815
of sartorius tendon, 815
of semimembranosus tendon, 815
of semitendinosus tendon, 815
of sternomastoid tendon, 815
of tendo Achillis, 814
local anesthesia in, 147
of tibialis anticus tendon, 814
posticus tendon, 814
open, 813
subcutaneous, 813
Tension sutures, adhesive support for, 198
Tent, operations in, 169
Teratomata, 327
Terebene as antiseptic, 72
Terminal anesthesia, 128
Testes, operations on, local anesthesia in, 152
Tetanus, 264
chloral in, 267
chloretone in, 267
control of spasms in, 267
elimination in, 267
Fourth-of-July, 270
head, 270
magnesium sulphate in, 268
phenol in, 268
postoperative, 270
prognosis, 270
prophylaxis, 265
removal of focus of infection, 267
serum treatment, 265. See also *Antitetanic serum.*
sodium persulphate in, 268
spasms in, 264
warm bath treatment, 269
T-fractures of lower extremity of humerus, 570
Thecitis, 817
Thermocautery, 80, 83
Thermoradiation in inoperable cancer, 332
Thiersch's solution, 41
as antiseptic, 68
Thigh, middle of, ligation of femoral artery in, 435
quadriceps extensor of, paralysis of, tendon transplantation in, 812
rider's, 788
Thirst, postoperative, 226
Thomas' knee-splint in knee tuberculosis, 675
splint in impacted fracture of neck of femur, 585
Thoracic aorta, aneurism of, 396
duct, wounds of, 460
nerve, long, injuries to, 896
Thoracoplasty, local anesthesia in, 148
Thorax, operations on, local anesthesia for, 147
Threading needle, method, 191
Throat, clearing of, in general anesthesia, 97
operations on, prevention of shock, 215
Thrombin as hemostatic, 342
Thrombophlebitis, septic, excision of pelvic veins in, 456
Thromboplastin in hemorrhage, 342
Thrombosis, 455
of portal vein, 457
treatment, 455, 456
Thumb, dislocations of, 639
proximal phalanx, 639
fractures of, 582
splint, Goldthwait's, 582
Thymol as antiseptic, 72
as local anesthetic, 137
Thyroid artery, inferior, ligation of, 410
superior, ligation of, 411
gland, operations on, local anesthesia for, 144
Thyroidectomy, local anesthesia in, 144
Thyrotoxicosis as factor in operation, 182
postoperative, 227
Tibia, bone grafts from, 772, 773
excision of, 733
fractures of, 603
after-treatment, 608
old, with vicious union, 608
shaft, 603
spine, 654
upper end, 603
osteotomy of, 716
of shaft, 716
resection of, 733
sarcoma of, 706
tubercle of, avulsion of, 603
Tibial artery, anterior, ligation of, 443
posterior, ligation of, 441
in middle of leg, 442
nerve, anterior, injuries to, 898
Tibialis anticus, tenotomy of, 814
transplantation of extensor proprius hallucis for, 809
for peroneus tertius, 810
of peroneus longus for, 810
posticus, tenotomy of, 814
Tic convulsif, 888
douloureux, 862. See also *Neuralgia, trifacial.*
Ticks, bites of, 276
Tied chain sutures, 200
Tincture of iodin, 68
Tinea circinata, 839
favosa, 838
kerion, 839
tonsurans, 839
trichophytina, 839
versicolor, 839
Tinnitus aurium, 890
Toes, operations on, local anesthesia for, 147
Toluenine as antiseptic, 65
Toluol method for catgut, 34
Tongue, carcinoma of, incurable, alcohol injections in, 869
forceps for general anesthesia, 95

Tongue, holding, in general anesthesia, 97
operations on, local anesthesia for, 143
psoriasis of, 834
Torsion in hemorrhage, 341
Tourniquet, impromptu, in hemorrhage, 335
Tow dressings, 41
Towels, 48
Toxemia, intestinal, 259
Toxemic tenosynovitis, 817
Toxic neuritis, 862
Toxins, erysipelas, in inoperable cancer, 332
Trachea, mucus in, after operation, 227
operations on, local anesthesia for, 143
Tracheotomy, local anesthesia in, 143
Traction, continuous, in fractures, 487
frame, lever, Zuppinger's, 494
in fractures, continuous, 487
measurement of legs in, 493
of femur, 490
temporary, 485
splint in tuberculosis of hip, 669
transverse, in fractures, 498
wire, from skin, in fracture, 493
Transfusion, blood, 348
agglutination test in, 355
donor in, 348
for prevention of shock, 216
Hartwell's method, 352
hemolysis in, 348
test for, 355
in hemorrhage, 343, 348
in leukemia, 466
in septicemia, 260
indirect, 353
amount of blood, 354
Lindeman's method, 353
sodium citrate method, 356
Soresi's apparatus for, 352
vein-to-vein, 348
Vincent's tube for, 354
Transplantation of extensor proprius hallucis for tibialis anticus, 809
of joints, 767
of nerves, heteroplastic, 857
homoplastic, 857
of peroneus longus for tibialis anticus, 810
of tendons, 805
after-treatment, 808
general principles and technic, 805
in paralysis of biceps of arm, 812
of extensors of hand, 812
of quadriceps extensor of thigh, 812
in paralytic talipes calcaneus, 812
equinus, 812
valgus, 811
varus, 812
indications and results, 808
of tibialis anticus for peroneus tertius, 810
Transplanted bone grafts, 511
Transverse traction in fractures, 498
Trapezius muscle, paralysis of, 795
Traumatic aneurism, 380
arteritis, 380
asphyxia, hemorrhage in, 360
congestion, 228
Traumatic delirium in fractures, 527
emphysema, 820
gangrene, 317
neuritis, 862
ossifying myositis, 792
paralysis in general anesthesia, 100
synovitis, 657
tenosynovitis, 817
Traumatism of arteries, 371
of joints, 650
of skin, 820
of veins, 446
Treatment, surgical, 17, 184
Trendelenburg's operation in varicose veins, 449
Trench-foot, 319
Trephining in basal fractures of skull, 536
Treponema pallidum, 283
Triangle, carotid, inferior, ligation of common carotid at, 407
superior carotid, 406
ligation of common carotid artery at, 408
Triangular bandage, 49
Trichinosis, 792
Trichloriodin as antiseptic, 69
Trichophytosis, 839
Trichorrhexis nodosa, 847
Tricot bandages, 55
Tricresol as antiseptic, 66
Trifacial neuralgia, 865. See also *Neuralgia, trifacial.*
Trigeminal nerve, operations on, local anesthesia for, 143
Tripolith bandages, 56
Tritetrabromnaphthol as antiseptic, 60
Trocar and canula, 79
Trombidiosis, 848
Trombidium irritans, 848
Trophic gangrene, 320
ulcers, 313
Tropocain as local anesthetic, 136
as spinal anesthetic, 156
Trypaflavin as antiseptic, 65
Trypsin injections in inoperable cancer, 333
Tubercle, carotid, 407
of tibia, avulsion of, 603
Tubercular lymphadenitis, 461
Tuberculin in tuberculosis, 257
of joints, 663
Koch's, 257
new, 257
Oberst, 258
Rückstand, 257, 258
Tuberculosis, 276
about nails, 848
as factor in operation, 182
bacillus emulsion in, 258
sensitized, 258
Bier's hyperemia in, 280
cutis, 837
diet in, 277
drugs in, 279, 280
fresh-air treatment, 278
heliotherapy in, 280
light treatment, 280
local treatment, 279

Tuberculosis of ankle, 678
of bones, 469
filling bone cavities from, 706
of elbow, 679
of hip, 665
abscess in, 672
acute stage, 666
ambulatory treatment, 668, 671
Bradford frame in, 666
complications, 672
convalescent stage, 668, 672
deformity in, 672
double, 673
immobilization in, 666, 668
in adults, 673
Lovett's splint in, 671
operative treatment, 673
plaster-of-Paris splint in, 668
subacute stage, 668
traction splint in, 669
of joints, 663
amputation in, 665
arthrectomy in, 665
constricting band in, 232
excision in, 665
formalin-glycerin in, 281
general treatment, 663
heliotherapy in, 664
hyperemic treatment, 664
injection treatment, 664
light treatment, 664
local treatment, 663
operative treatment, 664
protection of joint in, 664
rest in, 663
tuberculin treatment, 663
tuberculous foci in, 664
of knee, 674
amputation in, 677
arthrectomy in, 677
convalescence in, 677
excision in, 677
flexion deformity in, 675
gradual extension in, 676
heliotherapy in, 675
immobilization in, 674
old cases, 676
osteotomy of femur in, 677
protection from traumatism in, 675
Thomas' knee-splint in, 675
traction in, 675
of metacarpal joints, 680
of metatarsal joints, 680
of muscles, 792
of phalangeal joints, 680
of sacro-iliac joint, 680
of skin, 837
of wrist, 680
operative treatment, 281
predisposing causes, 277
principles of treatment, 277
prophylaxis, 276
rest in, 279
serum treatment in, 279
sunshine in, 279
surgical, Bier's hyperemia for, 232
sea shore treatment. 279
Tuberculosis, tuberculin in, 257
vaccine treatment, 279
verrucosa, 837
Tuberculous abscess, 281
aseptic aspiration, 281
Bier's hyperemia in, 282
evacuation, 282
bursitis, 819
fistula, 282
foci in bones, uncomplicated, 470
laryngitis, anesthesin in, 137
spondylitis, bone grafts in, 776. See also *Bone grafts of spine.*
tenosynovitis, 817
Tubes, drainage, 44, 45
glass, 46
rubber, 45
self-retaining, 46
Tumors, 323
benign connective-tissue, 323
epithelial, 324
extirpation of, 323
ganglion, 818
malignant. See *Cancer.*
of bones. See *Bones, tumors of.*
of muscles, 792
of nerves, 880
special tissue, 323
Turf-moss dressings, 42
Twilight sleep, 124
Tying knots, methods of, 190
with one hand, 203
Tylosis, 848
Typhoid arthritis, 660
osteitis, 469

Ulcers, 308
acute, 314
applications for, 308
bleeding, 314
chronic, 314
curettage of, 309
diabetic, 314
dressings for, 308
eczematous, 314
edematous, 314
excision of, 309
exuberant, 314
fungous, 314
indolent, 312
indurated, 313
inflamed, 312
irritable, 313
later results, 225
malignant, 315
Marjolin's, 315
neuralgic, 313
painful, 312
phagedenic, 313
pressure on, 309, 313
rodent, 315
scarification of, 310
scorbutic, 314
sloughing, 314
sluggish syphilitic, 302
tanner's, 315
trophic, 313

Ulcers, varicose, 310. See also *Varicose ulcers.*
Ulna, dislocations of, forward, 637
inward, 637
lower end, 638
excision of, 731
fractures of, 572
shaft, 573, 574
styloid process, 579
resection of, 731
sarcoma of, 707
Ulnar artery, ligation of, 424
nerve, dislocation of, 897
injuries of, 897
Ultra-violet rays in erysipelas, 263
Umbilical hernia, operations on, local anesthesia in, 150
Unconscious patients, moving, 184
Unguentum hydrargyri in syphilis, 286
Union, delayed, in fractures, 527
faulty, in fractures, 527
fibrous, in fractures, 528
Unna's zinc-gelatin dressings in varicose ulcers, 310
Upper extremities, nerves of, injuries to, 896
Urethra, operations on, local anesthesia in, 151
Urine, retention of, postoperative, 226
Urticaria, 827
Uterus, operations on, local anesthesia in, 152
preparation for, 180

Vaccines, 255
autogenous, 256
results from, 256
desiccated, in hydrophobia, 273
dosage, 256
in anthrax, 272
in boils, 253
burns of skin, 824
in eczema, 832
in erysipelas, 264
in furunculosis, 829
in joint infections, 257
in osteomyelitis, 257
in psoriasis, 835
in puerperal septicemia, 257
in ringworm of scalp, 840
in septicemia, 256, 260
in tuberculosis, 257, 279
mixed, 256
stock, 256
technic of injections, 258
Vagina, preparation of, for operation, 180
Vapor method of ether anesthesia, 109
Varicose lymphatics, 464
ulcers, 310
albuminuria in, 312
amputation in, 312
artificial scab treatment, 310
heliotherapy in, 312
Martin's treatment, 311
Skillern's treatment, 311
treatment, 311
zinc-gelatin dressings in, 310
veins, 448
circumcision of leg in, 452
Varicose veins, eczema with, 448
elevation treatment, 448
excision of, 450
by inversion, 452
segmentary subcutaneous, 452
extending above knee, 448
injection treatment, 453
ligation of femoral artery for, 453
multiple, 452
of internal saphenous vein, 449
of legs, 448
operative treatment, 449
subcutaneous enucleation of, 452
Trendelenburg's operation in, 449
Variot's method of removing tattoo marks, 849
Vaselin, 58
Vault and base of skull, fractures of, 537
of skull, simple linear fractures, with symptoms of brain compression, 532
without symptoms of brain compression, 532
Veins, 446
transplanted, for tendon reconstruction, 803
traumatism of, 446
varicose, 448. See also *Varicose veins.*
wounds of, 446
Vein-to-vein blood transfusion, 348
Vena cava, portal vein and, anastomosis between, 458
Venesection, 453
Venous infusion in local anesthesia, 132
puncture, 453
Ventilation of hospitals, proper, 21
Ventral hernia, operations on, local anesthesia in, 150
Verruca, 841
plana, 842
Vertebræ, dislocations of, 620. See also *Dislocations of vertebræ.*
fractures of, 537
immobilization in, 538
with compression, 538
sprains of, 651
subluxations of, 623
Vertebral artery, ligation of, 410
Vessels, 81, 84
Vibration in chronic inflammation, 249
Vibratory massage in neuralgia, 864
Vienna anesthetic mixture, 119
paste as caustic, 74
Vincent's glass tube for indirect blood transfusion, 354
Violin hold of operating scalpel, 184
Volkmann's sliding splint, 491
Volumetric analysis of Dakin's fluid, 61
Vomiting, postoperative, 226
Vulva, eczema of, 832

Warbasse's cone vaporizer for ether anesthesia, 111
method for dressing fractures of clavicle, 553
of continuous divulsion in fractures 496, 497

Warts, 324
Wasps, stings of, 276
Wassermann test in syphilis, 299
Water as local anesthetic, 139
bed for bed-sores, 313
boiling, sterilization by, 31
cushions, 23
sterile, 57
preparation of, 32
sterilizer, 30
Water-glass bandages, 56
Waxed paper protective, 54
Wedge-eyed needles, 79
Weight and pulley traction in fractures, 487
Wen, 845
Wet applications in inflammations, 234
Wick drains, 47
Wicking, iodoform, 40
Wire coverings for protection of wounds, 210
frame suspension splints, 487
sutures, 38
traction from skin in fractures, 493
Wiring in aneurism, 382
in fractures, 503
of lower jaw, 545
Woelfler's solution, 73
Wood-fiber dressings, 42
Wood-wadding dressings, 42
Wood-wool dressings, 42
Wounds, 166
accidental, 166
treatment, 186
adhesive straps for, 187
bullet, 222
clean, no-dressing treatment, 210
closure of, 187, 188. See also *Sutures.*
complications, 211
contractions of, 225
distortions of, 225
drainage of, 204
dressings of, 205
subsequent, 211
fever from, 213
foreign bodies in, *x*-ray for removal, 223
from explosive bullets, 222
gaping, 212
general considerations, 166
granulating, 220
gunshot, 222
hemorrhage in, 212
incised, 219
infected, 27, 28, 211, 237. See also *Infected wounds.*
lacerated, 219
later results, 225
metallic bodies in, microphone for removal, 224
Michel clamp for, 187, 189
of arteries, 371
of bursæ, 819
of joints, 654
aseptic, 654
bullet, 656
Wounds of joints, gunshot, 656
incised infected, 655
lacerated infected, 655
punctured, 654
with compound fractures, 657
of lymphatic vessels, 460
of muscles, 791
of nerves, 852
of receptaculum chyli, 460
of skin, 820
of tendons, 796
old, 816
of thoracic duct, 460
open, rubber protective for, 209
operative, 166
method of making, 184
punctured, 219
septicemia from vaccines in, 257
shell, 222
shrapnel, 222
sloughing, 221
small, treatment, 187
soiled, treatment, 186
with earth, 221
stab, 219
suppurating, bitartrate of potassium for, 212
hot-air treatment, 187
wire covering for protection of, 210
with foreign bodies, 222
with loss of substance, 220
Wright's solution, 58
Wrist, ankylosis of, arthroplasty for, 764
dislocations of, 638. See also *Dislocations of wrist.*
excision of, 746. See also *Excision of wrist.*
sprains of, 652
subluxations of, spontaneous, 638
tuberculosis of, 680
Wrist-drop, 896
arthrodesis in, 739

Xanthoma, 843
X-rays for removal of foreign bodies in wounds, 223
in inoperable cancer, 332
in pseudoleukemia, 465

Yaws, 303
salvarsan in, 303

Zinc chlorid as antiseptic, 71
paste, 74
oxid as antiseptic, 71
gauze, 41
stearate as antiseptic, 71
sulphate as antiseptic, 71
sulphocarbolate as antiseptic, 71
Zinc-gelatin dressings in varicose ulcers, 310
Zuppinger's lever traction frame, 494
Zygoma, fractures of, 540
resection of, for exposure of temporomaxillary joint, 740

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